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# A Framework of Network Virtual Experiments for Control Courses

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## Abstract

With the development of computer science and Internet, using the virtual experiments to help improvement of teaching effects is becoming more and more popular. This paper describes a framework of virtual experiments for control courses in college. It includes three layers. The user interface layer bases on Flash technology, the data exchange layer bases on Webservice technology, the calculation module in data process layer bases on Modelica language. This framework provides a friendly user interface and solved the problem that the control experiments need multifarious calculation when simulation the real phenomenon. An example of virtual experiment is also be shown in the final of this paper. This framework can also be used for virtual experiments of other courses in college education.

**Index Terms:** virtual expriment; virtual lab; modelica; control course

## 1. Introduction

Virtual labs or virtual experiments are hot words in today’s education and computer research area. With the developing of multimedia technology, network technology and the computer science, the technology to realize a virtual lab is become more and more mature. Virtual lab can solve the problems such as lack of experiments apparatus, remote education and online demonstration in the classrooms.

There are many virtual labs along the whole world. MBL chemistry laboratory in Indiana University, Digital organic chemistry laboratory of University of Illinois at Chicago，LAAP（Learn Anytime Anywhere Physics）of North Carolina State University[1]. There are different infrastructures for virtual labs. For the convenience to use, the B/S(Browser/Server) infrastructure becomes the dominative solution for the virtual lab.

Control courses include the automatic control theory, the computer control, processing control etc. These courses are important courses for engineer college education. For a college student, the control courses are a bit of abstract and the experiments can help him to understand well. The experiments in the class also can improve the teaching effects. With the help of virtual lab, the teacher can demonstrate the control theory in the classroom, and will provide the online lab for 24 hour access in whole day.

This paper discuss a virtual experiment framework based on the RIA (Rich Internet Application) technology. In section 2, the general framework will be introduced. In section 3, each technology used in three layers will be

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introduced. It includes the user interface layer, the data exchange layer and the data processing layer. After that, an example of an experiment from the course “process control” will be shown and section 5 is the conclusion.

## 2. General framework

A virtual experiment includes three layers: the user interface layer, the data exchange layer and the data process layer. The general structure of the virtual experiments system shows in the fig. 1

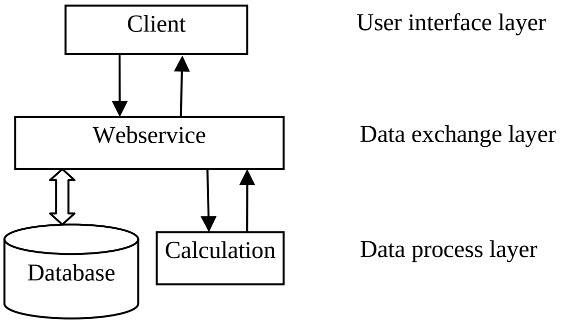

Fig.1 The general architecture of the virtual experiment

The user interface layer accepts the user’s(student or teacher) input and displays the experiments phenomena. The data exchange layer is running at the server side. It accepts the data from the client (user interface layer) and gives them to the data process layer. It also give back the result data to the user interface layer, such as the data from database or from the calculation modules. For a B/S structure, the client is based on the browser, such as Internet Explorer, Firefox, Chrome.

Data process layer includes the database and the calculation modules. A Database stores the experiments records and experiments reports, which can be used for the teacher to exam or correct. The calculation modules calculate the experiments result according to the user’s operation. The result data can be transferred back to the client side through the data exchange layer.

The data exchange layer provides a data channel from the client to the server. And the detail description of the three layers is in section 3.

## 3. Detail discuss of the three layers

### *3. 1 The user interface layer*

For a B/S structure application, RIA(Rich Internet Application) is a technology that provide user-friend interface in the browser. Now it is a hot technology on the Internet and many relative technologies appeared. The main RIA solution includes Java FX, Flash and Silverlight. The Flash technology is the first appeared technology and now is becoming the dominating technology in the RIA application. In the framework of this paper, the Flash technology is chosen to build the user interface layer.

The Flash application(or can be called Flash movie) runs in the browser as a plugin and now almost every browser support the Flash movie. The file extension of the Flash movie is ".swf". The Flash provides the vector drawing and timeline tools to make it easy to build a movie. And it also provides the user interface elements such as button, list, inputbox, etc. The Flash supports a script language called AS(action script) and can improve the user interaction with the application.

In the client application, each experiment apparatus is a “component” and it have its own visual properties and calculation properties. The visual properties define the view of the show of the component, such as the movie clips or pictures that can be shown in the experiment scene. The calculation properties are the properties that

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used for the calculation in the virtual experiment system. The calculation properties is driven the visual properties and make the virtual apparatus to action according to the user's input.

For example, a bottle is an apparatus in the experiments. One of the visual properties of the bottle is a movie clip that show the liquid level change inside the bottle. And the calculation properties of the bottle are the diameter, the current liquid level and the whole high of the bottle. The change of the liquid level property driven the movie clip behavior, so the user can see the liquid inside the bottle is increment or decrement.

Generally, there are two ways to make a Flash movie, one is using the tool Flash Professional, the other is using the Flex platform. Flex is a highly productive, free, open source framework for building expressive web applications that deploy consistently on all major browsers, desktops, and operating systems by leveraging the Adobe® Flash® Player and Adobe AIR® runtimes[2]. Inside the Flex environment, Adobe provided more components than in the Flash Professional environment. The example virtual experiment Flash movie in section 4 is developed by Flex builder 3.

The action script language used in the Flash can do some simple calculation and logical control of the workflow, but it is limited in the data process and calculation capacity. Flash alone is not enough to calculate the experiment results in many control course, these work can be done in the data process layer. To manipulator the data in the data process layer, the user interface layer (Flash) is communicate with the data exchange layer.

### *3. 2 The data exchange layer*

As discussed in the section 2, the data exchange layer is a "glue" between the user interface layer in the browser and the data process layer in the server. To solve the problem that the data exchange maybe across the firewalls in the Internet, the Webservice technology is used to build the data exchange layer.

In the server side, some Webservice modules is designed and run under Tomcat 6 environment. These Webservice modules are the modules to access the resource on the server side and in the data process layer. For example, the data accessing module is provide the functions to store the data to the database or query the data from database. The "call the calculation" module is used to run the calculation program and get the results, then send the results back to the user interface layer ( Flash program).

In client side, Flex have a "Webservice" component which can make the Flash application call the Webservice functions easily. It only needs to provide the Webservice WSDL(Web Services Description Language) url to the Flash so the service can be access directly. The relation of the user interface layer and the data exchange layer is shown in the fig. 2.

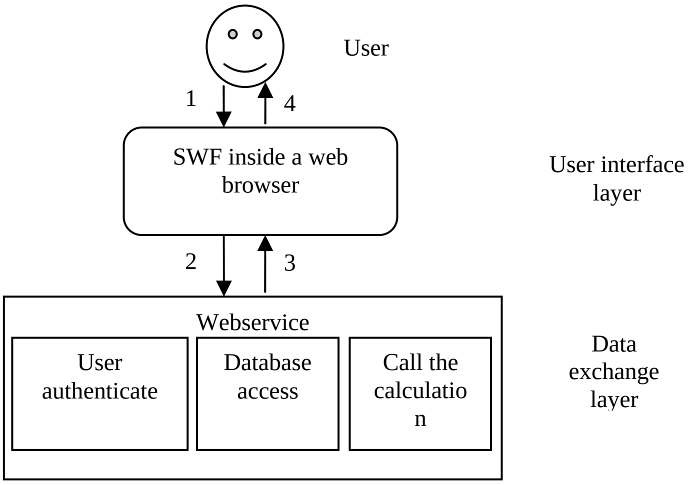


Fig.2 The data flow between the user interface layer and the data exchange layer

The data flow between the user interface layer and the data exchange layer is as follow:

1. The user operation in the virtual experiments environment (Flash);

2. The Flash get the operation and change the experiment components' properties, then it pass the request to the Webservice.

3. The server side receives the service requirements and call correspond modules, such as the user authentication, the database access (store or query the data) or call the calculation modules. Then the Webservice return the result data to the client side.

4. The client side (Flash) changes the visual elements of the scene and give the respond to the user. So the user get the experiment result of his operation.

During the experiments processing, the data flow from 1 to 4 is continuous until the end of the experiment.

### *3. 3 data process layer*

Data process layer includes the functions about the data store and data process. One is the data service provides by a database. In this framework, we use the Oracle as the main database. The database access function is not the key point in this paper.

In the control courses, it always has the requirement of solving the differential equation, and includes the time domain and frequency domain analysis. Many virtual labs related to control course area are using the Matlab as the basic compute module. But the Matlab is a commercial software and need pay a highly fee for widely use, also it lack of the ability to build a friendly use interface. For Matlab alone is also hard to build a B/S mode application[3-4]. In this paper, we choose Modelica to build the calculation modules.

Modelica is a non-proprietary, object-oriented, equation based language to conveniently model complex physical systems containing, e.g., mechanical, electrical, electronic, hydraulic, thermal, control, electric power or process-oriented subcomponents. Modelica is a free language and is developed by the (non-profit) Modelica Association since 1996. There are many Modelica simulation environments. Commercial Modelica simulation environments include Dymola, MapleSim, MathModelica, SimulationX, etc. Free Modelica simulation environments include OpenModelica, SCICOS, etc. In the Modelica official website (www.modelica.org) can find the tools list[5]. Carla Martin-Villalba introduced a virtual experiments environment that is developed by the Modelica language and using the Dymola tools[6].

In this paper, we used the OpenModelica and Simforg to build the control system model and complier it to the execute file that can calculate the experiment results under the control of the web service module.

OpenModelica provide a complier tool "OMC" to complier the Modelica model (MO files) to execute files (exe file in Windows platform). Simforg provides a graphics interface that can let user easy to build the model.

To build the calculation module, first is to build the experiments model under Simforg (OpenModelica). For the control course's experiments, the system architecture of the experiment apparatuses are fixed usually, and the student only change the parameters of the controllers for the control aims. So the system model of one experiments is fixed. It can be modeled using Modelica language into MO files. Then it can be transferred to EXE file. The EXE file can be executed in the Windows platform, when it runs, it can read the model parameters from a parameter file. Each time the student changes the parameters in the experiment, the parameters of the experiments can be transferred to parameters file. Then the model's EXE file execute and get the result file( usually is a .plt file).

The model is built and compiled to EXE file using Openmodelica and Simforg. The EXE file is the calculation module of the experiments. Normally, one experiment have one EXE file correspondingly. And the EXE file don't change during the experiment.

To integrate the Modelica into the system, the system architecture see the fig. 3.

The web service manage the calculation module. When the students change the properties of the apparatus in the experiments, such as he change the parameters of the controller ( PID parameter ), then the parameters will be write into the parameter file.( the flow 1 in the fig.3). The Webservice module will call the EXE file and get the result.( the flow 2 in the fig. 3). When the execution is end, the Webservice module read the result file and transfer the result to the client side. Then the client side can make the change of the scene according to the calculation result. The experiment has the action to the student operation.

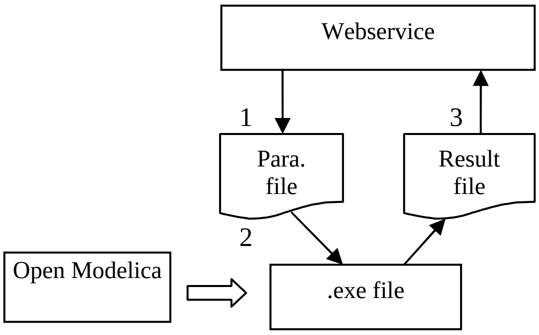


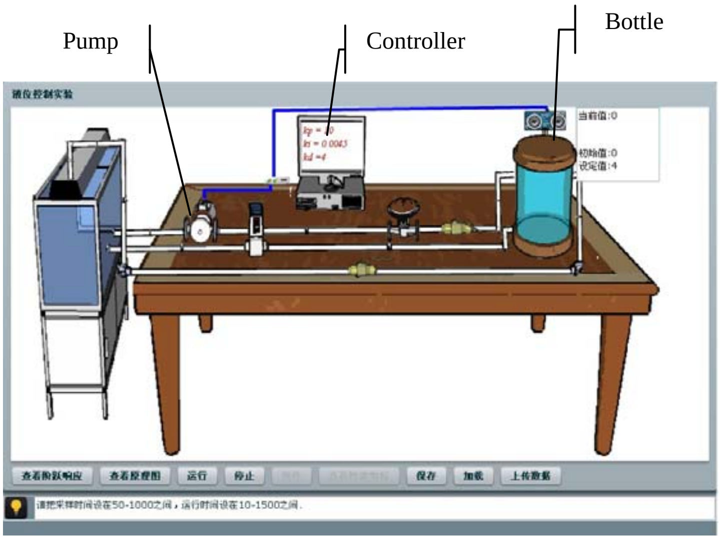
Fig. 3 The relation of calling the calculation module.

## 4. An example of the expriment

Here we present an example of the virtual experiment in the curse of “processing control”. The experiment is to control the liquid level in the bottle. To change the controller’s PID parameters, the pump will work under the controller manage, and the liquid level will changed.

The aim of the experiment is to set the good control parameter , to get good response time and maximum percent overshoot of the liquid level change. The whole experiment interface see the fig. 4.

The parameters setting window see the fig.5. and fig. 6 is the result curve of the liquid level in the bottle.

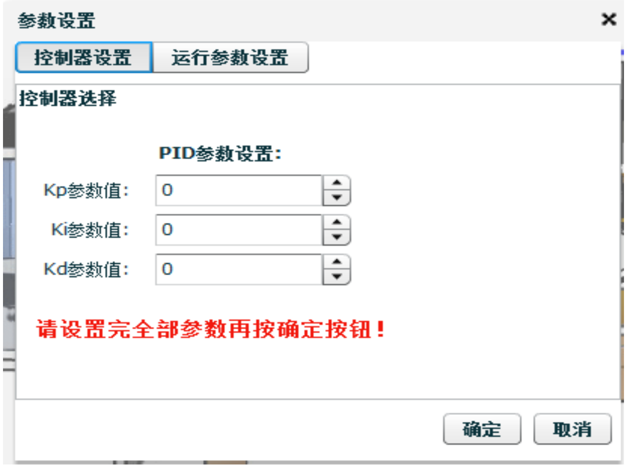


kp = 10
ki = 0.0043
kd =4

当前值:0
初始值:0
设定值:4

请把采样时间设在50-1000之间，运行时间设在10-1500之间。

Fig. 4 The experiment user interface



控制器选择

PID参数设置：

Kp参数值： 0

Ki参数值： 0

Kd参数值： 0

请设置完全部参数再按确定按钮！

Fig. 5 the setting window of the controller

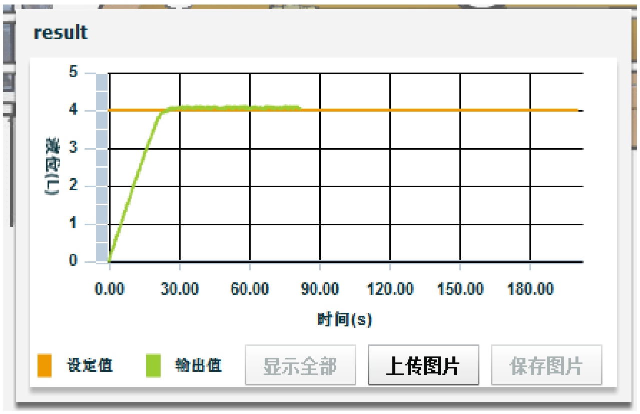


Fig.6 The result curve of the liquid level in the bottle

## V. Conclusion

The virtual experiment should have a “real interface” and “real behavior” like the reality experiment. That makes students to have a real feeling when they operate in the virtual world.

This paper discusses a framework of virtual experiment for control curses. To improve the reality of the experiments interface, the experiments apparatus and scene are developed in Flex and run as a Flash movie in the browser. To make the apparatus behave like reality, the virtual component is driven by the model in the server. And the object-orient model language Modelica is be used. The data exchange layer using the Webservice to provide several service for data exchange between the interface and the background. The whole framework has three layers.

This framework provides a friendly user interface and solved the problem that the control experiments need multifarious calculation when simulation the real phenomenon. Modelica is a free language and easy to use. This framework also can be used for other subject to development virtual experiments besides the control curse.

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