

Practice and Evaluation of Simulation Technology in Computer Science Instruction

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Abstract

A demonstration and experiment system for computer network courses has been constructed. This system is made up of two parts, one of which is the demonstration system for teachers to demonstrate in class, and the other is the experiment system for students to do experiment in the laboratory or after school. This system was applied in the education of undergraduate courses in a university. The results show that it can help to enhance student achievements and improve the teaching effectiveness through introducing simulation technology in computer education.

Keywords: Computer education; Simulation; Demonstration and experiment system; Evaluation.

1. Introduction

In recent years, computer and simulation technology was widely used in the education of multiple disciplines [1-4]. The application of simulation technology in computer education is studied in this paper. In the education of computer network courses [5] large numbers of network protocols will be involved, which have the characteristics of abstraction, asynchronism, concurrency and multitasking [6]. At present teachers usually teach the network protocols through oral explanation or recurring to some legends or animations in class, and let students to implement some simple protocol mechanisms through programming in the laboratory. The traditional education methods have the ubiquitous disadvantage of that teachers are very toilsome to explain the protocols and student are also very hard to understand them. Therefore some new education methods should be designed for teaching network protocols in computer network courses to let students intuitively observe the complex behavior in the protocol run process and accordingly comprehensively understand the protocol mechanisms and control strategies of network protocols.

On the other hand, there exist some outstanding network simulation tools in the computer network research area, such as NS2 and OPNET [7,8], which provide very powerful simulation functions for network protocols, and through which it is very convenient to create the running environment for various protocols and it is very easy to display the protocol behavior visually. Nevertheless these simulation tools are very hard to install and utilize. At present they are used by computer network researchers to study, extend and develop new protocols. For beginners, it is not realistic to let them learn and use these simulation tools directly.

In order to solve above contradiction, we constructed a NS2-based demonstration and experiment system for computer network courses, which builds a bridge between network the simulation software NS2 and the students who want to learn computer network courses. Through this system, the students not

only can leave out the difficulty to learn the network simulation software NS2, but also can make use of its powerful simulation functions to carry out network simulation experiments, and consequently understand the complex behavior of network protocols more comprehensively. This demonstration and experiment system can be applied to the education of computer network related courses. In order to verify the teaching effect of the NS2-based demonstration and experiment system, an experiment was carried out on the teaching of “Computer Network Theory” course and the effect was evaluated.

2. Simulation software overview

Network simulation is a kind of technology that simulates the network behavior through mathematical modeling and statistical analysis method and then obtains the specific parameters which reflect the characteristics of the network. NS2 is one of the most famous network simulation software which was developed by LBNL network research group at UC Berkeley in the USA. It is primarily useful for simulating local and wide area networks, no matter what are wired or wireless networks. It has great value for network researchers, especially for the designers of new network protocols.

NS2 simulator is based on two languages: an object oriented simulator, written in C++, and a OTcl interpreter, used to execute user’s command scripts. For efficiency reason, NS2 separates the data path implementation from control path implementations. In order to reduce packet and event processing time, the event scheduler and the basic network component objects in the data path are written and compiled using C++. These compiled objects are made available to the OTcl interpreter through an OTcl linkage that creates a matching OTcl object for each of the C++ objects and makes the control functions and the configurable variables specified by the C++ object act as member functions and member variables of the corresponding OTcl object. In this way, the controls of the C++ objects are given to OTcl. It is also possible to add member functions and variables to a C++ linked OTcl object. The objects in C++ that do not need to be controlled in a simulation or internally used by the other object do not need to be linked to OTcl. Likewise, an object can be entirely implemented in OTcl.

In order to observe and analyze the simulation result intuitively, NS2 provides a graphical simulation display tool called Network Animator (NAM). NAM has a nice graphical user interface similar to a CD player, and also has a display speed controller. Furthermore, it can graphically present information such as throughput and number of packet drops at each link, although the graphical information cannot be used for accurate simulation analysis. The design theory behind NAM was to create an animator that is able to read large animation data sets and be extensible enough so that it could be used indifferent network visualization situations. Under this constraint NAM was designed to read simple animation event commands from a trace file.

3. Demonstration and experiment system

A NS2-based demonstration and experiment system for computer network courses has been constructed. This system is made up of two parts, one of which is the demonstration system for teachers to demonstrate in class, and the other is the experiment system for students to do experiment in the laboratory or after school. In this system we do not need to modify the protocols that NS2 has already implemented, need to add new protocols neither. Therefore, we do not need to add or modify the C++ code in NS, need to recompile NS neither. The NS simulation process using by this demonstration and experiment system is described in dotted line frame part. The process only includes designing or modifying Otel script, running NS simulation and observing the results.

The demonstration system is used for teachers to demonstrate in class. The NS process using by this demonstration system is described. It is made up of two processes. One is the experiment database developing process, and the other is the demonstrating process in class.

The purpose of this process is to prepare the material for classroom demonstration and as a result to form the experiment database. The database can be modified and cited by developers or teachers conveniently when needed. The steps to develop the experiment database are as follows.

Firstly, the developers design the Otcl script according to the contents of the courses. For example, in order to demonstrate the slow start mechanism in TCP congestion control, we design two pieces of Otcl script. One is named SS.tcl, and the other is named NoSS.tcl. Both of them use the similar simulation environment such as the topology and the traffic type. The difference between them is that the former uses TCP with slow start mechanism, but the latter uses TCP without slow start mechanism. The Otcl script code is omitted due to paper length limitation.

Next, run NS simulation on the designed Otcl script, then the corresponding NAM trace file will be created automatically. In the above example, we run NS simulation on SS.tcl and NoSS.tcl respectively, and then we can get two corresponding NAM trace files. They are named SS.nam and NoSS.nam respectively.

Lastly, observe and analyze the experiment results using the NAM tool. Also in the above example, we open SS.nam and NoSS.nam in the NAM tool respectively and compare the two experiment results. The emphasis is whether the results reflect the difference between TCP with slow start mechanism and without slow start mechanism. The results also show the changing process of the congestion window size, from which students can understand the slow start and congestion avoidance mechanisms in TCP congestion control comprehensively.

If the results are satisfied with the requirements of the classroom demonstration, add the Otcl script and NAM trace file into the Otcl script database and NAM trace file database respectively.

Otherwise, modify the Otcl script and repeat the above process, i.e. running NS simulation, observing the results and making the decision to add the script and file to database or not.

After the development work is finished, the experiment database creates, which is made up of the Otcl script database and the NAM trace file database. The experiment database can be used for classroom demonstration or be modified as required.

The demonstrating process in class is described below the dotted line. The detailed steps can be described as follows.

First of all, the teachers select the appropriate material from the experiment database according to the educational purpose. For instance in order to explain the slow start mechanism in TCP congestion control, the NAM trace files named SS.nam and NoSS.nam above can be choose. Note that here only NAM trace file is needed. The Otcl script file is not needed at all.

In the next place, import the selected NAM trace file into Microsoft Powerpoint document. We have solved the problem to open NAM trace file in Powerpoint document, hence the teachers can insert the needed NAM trace file into the Powerpoint document which they want to use in class very conveniently.

The ultimate step is to demonstrate the results in class. In above instance, teachers only need to press the "Demo" button in the Powerpoint document page, then the corresponding NAM trace file can be opened using the NAM tool automatically. The work process of the slow start mechanism can be demonstrated to the students.

The experiment system is used for students to do experiment in the laboratory or after school. The NS process using by this experiment system. We can see that the remarkable characteristic of the experiment system is that it provides a visualized interface. The visualized interface provides an integrated experiment environment through which students can build simulation environment, design Otcl script, run NS simulation and observe the results.

We have made use of the nsBench software [9] to build the integrated experiment environment of the student experiment system, which was developed by the MNLAB laboratory of DePaul University. The goal of nsBench project is to develop supporting tools that enable creating, analysing and visualizing NS2 simulation script and trace automatically. Through this software the beginners of NS2 can build the needed simulation environment in a visualized way, thereby they don't need to design the Otcl script themselves which is hard to beginners.

The process for students to do experiment using this system is as follows.

In the first place, use nsBench software to build the simulation environment according to the experiment guidelines. The detailed work includes:

- (1) Insert the network nodes.
- (2) Insert the links between the nodes and set the link parameters such as bandwidth, time delay, queue type and queue size.
- (3) Insert the agents of transport layer and set the related parameters such as window size and packet size for TCP agent.
- (4) Insert the traffic source and set the related parameters such as message size and message interval for CBR traffic.
- (5) Set the start and stop time of the traffic source as well as the finishing time of the simulation.
- (6) Set the filename of the simulation results such as the filename of the NAM trace file.

Secondly, automatically create the Otcl script corresponding to the above simulation environment by executing the proper menu command provided by nsBench software.

Next, run NS simulation by executing the proper menu command with the created Otcl script as input, then the corresponding NAM trace file will be created.

After the NS simulation is finished, the created NAM trace file will be opened by the NAM tool automatically. Then the students can observe and analyze the experiment results.

4. Education effect evaluation

In order to verify the teaching effect of the NS2-based demonstration and experiment system, an experiment was carried out on the teaching of "Computer Network Theory", one of the main courses for the undergraduates of 2009 computer science and technology major in the School of Computer and Information Technology, a University. By using cluster sampling method, 100 students were selected as the research objects, including 63 boys and 37 girls. Random number table method was used to divide them into the study group and the control group. There are 32 boys and 18 girls in the study group while 31 boys and 19 girls in the control group. Differences of the general information of the students between the study group and the control group are not statistically significant.

Traditional teaching and experiment methods were adopted in the control group. That is, teachers orally explain network protocols to students and deepen their intuitive feelings through some graphics and animations. In the experiment class, students program to realize some simple protocol mechanisms. As to the study group, the NS2-based demonstration and experiment system was used both in teaching and

experiment. Teachers teach the class by using the demonstration system while students use the experiment system to do experiments.

The two groups both have 80 class hours which is comprised of 56 theory hours and 24 experiment hours. Three teachers and two teaching assistants are involved in the teaching of the control group and the study group. Three teachers all have rich teaching experience and senior professional title. The teaching assistants are graduates of the major of computer science and technology who give experiment tutoring to the students.

After the teaching, we did learning effect evaluation to the 100 students and information feedback investigation for the teaching effect. The learning effect evaluation is composed of the protocol knowledge theory evaluation and network operations skills evaluation. The protocol knowledge theory evaluation is carried out by the 100-score scale semi-open-book examination. To evaluate the network operating skills, 3 senior professors form an expert team. It is carried out through the form of actual operation, defense and quiz. This part is also 100 scores. At last, two scores were merged into a total score in 100-score scale according to 50% of weight respectively. Students were divided into A (90-100 scores), B (80-89 scores), C (70-79 scores), D (60-69 scores) and E (less than 60 scores), or 5 levels according to their total scores. In the feedback investigation for the effect of teaching the homemade questionnaires were adopted to investigate the evaluation of the teaching effect from the students of the study group.

SPSS statistical software [10] was used for data entry and statistical analysis. The quantitative data was analyzed by the paired *t*-test. The Wilcoxon test was used for the ranked data. The learning effect evaluation results of the study group and the control group students are shown in Table 1. The evaluation results to the NS2-based demonstration and experiment system used in the teaching of computer network theory from the 50 students of the study group of are shown in Table 2.

The evaluation results of the learning effect of the students in Table 1 shows that the operation scores, the theory scores and the total scores of the study group are significantly higher than that of the control group. The difference is statistically significant ($P < 0.001$). The grade evaluation comparison results also show that the study group students learn better than the control group ($P < 0.01$). The results indicate that it is helpful to improve the learning effect of the students through introducing network simulation software into the teaching and experiment of computer network course.

The evaluation results of the teaching effect from the 50 students of the study group in Table 2 show that the proportion that who thinks the new teaching method is effective is higher than 65%. Among which the percentage of students who believe that “Significantly improve my interest and enthusiasm in learning computer network”, “The method is intuitive and vivid, improve my understanding of the theoretical knowledge”, “Effectively improve the network operating skill levels”, “Improve the ability to solve practical problems of network” and “Effectively improve the teaching quality of computer network theory course” are all more than 85%. The proportion of 90% students believes that it has effectively improved the teaching quality of computer network theory course through introducing network simulation software. This shows that the students of study group have a positive evaluation on the new teaching method on the whole and it is feasible to promote the new teaching method.

Table 1. The learning effect evaluation results of the study group and the control group students

Group	<i>n</i>	Score evaluation ($\bar{X} \pm s$)			Grade evaluation (person)				
		Operation scores	Theory scores	Total scores	A	B	C	D	E

Study group	50	84.42±5.62	82.76±7.10	83.59±6.56	10	14	17	7	2
Control group	50	73.61±6.78	68.47±5.90	71.04±6.58	5	9	14	17	5
Statistic		11.225	10.174	10.446	8.378				
<i>P</i>		<0.001	<0.001	<0.001	<0.01				

Table 2. The teaching effect evaluation results from the 50 students of the study group

Evaluation items	Quite effective	Effective	Hard to say	No effect
Significantly improve my interest and enthusiasm in learning computer network	43(86)	5(10)	1(2)	1(2)
The method is intuitive and vivid, improve my understanding of the theoretical knowledge	44(88)	4(8)	2(4)	0
Effectively short the distance between the theoretical knowledge of protocols and practical issues	38(76)	9(18)	2(4)	1(2)
Effectively improve the network operating skill levels	44(88)	3(6)	1(2)	2(4)
Improve the ability to solve practical problems of network	43(86)	4(8)	3(6)	0
Enhance the awareness to apply protocol theoretical knowledge to network practice	35(70)	10(20)	3(6)	2(4)
Promote teaching and learning, and intercommunication between teachers and students	33(66)	9(18)	5(10)	3(6)
Effectively improve the teaching quality of computer network theory course	45(90)	2(4)	2(4)	1(2)

5. Conclusions

In order to solve the realistic problems in the teaching and experiment of computer network courses, we constructed a NS2-based demonstration and experiment system for computer network courses. The feature and innovation of this system can be described as follows:

(1) The network simulation software NS2 has been introduced to the experiment of computer networks, which usually was used in the network research area. As a result, the application scopes of NS2 were extended, and at the same time it provided the feasibility to carry out the complex experiment in the education of computer networks.

(2) The whole system possesses two kind functions, i.e. the classroom demonstration function and simulation experiment function. The former only demonstrates the experiment results, while the latter provides the guidelines to complete the whole experiment. The two kind functions can be used in different occasions for teachers and students.

(3) The experiment database is provided with the type of software component. This method can increase extensibility of the system, improve system development efficiency and realize software reuse.

In order to validate the effect of introducing network simulation software into the teaching and experiment of computer network course, the experiment was carried out in the education of undergraduate course "computer network principle" in a University. The results show that it can help to enhance student achievements and improve the teaching effectiveness through introducing simulation technology in computer education.

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