The Application of Computer Network Systems in Experimental Physics Courses

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(Received 07/31/2009; accepted 10/23/2009)

Computers and network technologies are widely used in introductory and experimental physics courses. We introduced a new computer network system, the intelligent experimental network system, to collect the data and results students produce while they are doing experiments in the laboratory. We then organized the collected information into a database and analyzed it to discover the system's merit for increased educational effectiveness. For several semesters, teachers have used this system to manage their teaching and uncover the difficulties and misconceptions students have during the experimental course. In this paper, we describe and analyze the intelligent experimental network system in terms of its network structure, communication interface, software, application to laboratory teaching, and future prospects. Our research-based survey demonstrates the positive attitudes of students toward this computer system and method of laboratory teaching.

Key words: computer assisted education; experimental physics teaching course

I. INTRODUCTION

In recent years, experimental physics courses in universities have used various types of instruments and equipment. By using the rich and diverse set of equipment introduced to them in these courses, students can learn the basic concepts and content, as well as methods of experimentation in physics. Coinciding with increased development of modern technologies, the setting and development of these instruments used to teach experimental physics have improved quickly. Both the usefulness of these instruments and advances in technology has promoted reform in the design of experimental physics courses. But is it effective for traditional and classic physics experiments to be integrated with modern technology? Can the teaching of experimental physics be improved through an intelligent modern network? That this integration is effective and feasible for improving teaching and learning is confirmed by our research on the implementation of the intelligent experimental network system.

In recent years, we have developed the intelligent resonator network system and intelligent rotational inertia network system. These systems have been used in the teaching and management of experimental physics courses.

In this paper, we introduce and analyze the structure, characteristics, key technology, and application of the intelligent resonator network system as an example of the type of systems we have been developing. This system was designed in the physics laboratories of Tongji University and is used to manage the teaching of the "Resonator Experiment." The experimental devices of this system are used to study the properties of free vibration, damped oscillation, and forced vibration, including the measurement of the damping coefficient, the phase difference in object oscillation and the force in forced damped oscillations, the frequency characteristic curve, and the phase frequency response curve of forced vibration. (Fang & Chen, 2006)

II. BASIC STRUCTURE OF THE RESONATOR NETWORK SYSTEM

The intelligent resonator network system consists of three layers, which we have diagramed in figure 1. The lowest layer is the experimental device, made up of resonators and controllers, which students use to collect the data. The middle layer is a hub, which transfers the data from the lowest layer to the highest layer, the computer. The teacher uses the computer to manage the experiment.

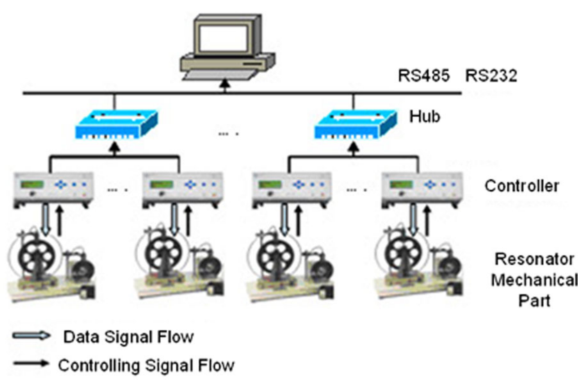

Figure.1: The structure of the intellectualized resonator network system.1

A. System structure

The lowest layer of the intelligent resonator network system is constructed from mechanical resonator parts and the controllers. The major mechanical parts of the resonator are a copper balance wheel, a damping coil, an electric motor, two photoelectric sensors, and a link. The primary controller consists of a LCD screen, several push buttons, and a potentiometer. Internally, the controller consists of a power supply circuit board, flash lamp circuit board, and other electronics.

In the experiment, the students use the two photoelectric sensors to record periodic time (10T) and amplitude (θ) as a balance wheel is undergoing stable, forced vibration. The stroboscopic method is used to measure the phase difference between the oscillating object and the forcing in this stable condition, which is the same as the phase difference φ between the balance wheel and electric motor. A second method for measuring the phase difference is to first read the time interval between two photoelectric sensors on the balance wheel and electric motor, get the value of φ calculated by a controller, and then import the data into the computer. The results of the two methods of measurement can then be compared and analyzed.

As shown in figure 1, the second layer of the structure is the hub, which primarily contains a single chip micyoco (SCM) as well as RS-485 and RS-232 interface circuits. The RS-232 interface circuit is used to deal with data communications between the controller and hub, while the data transmits between the hub and computer through a RS-485 communication interface. Compared with RS-232, the transmission distance of the RS-485 bus is longer, but the speed is faster; also, RS-485 meets the requirements for a truly multi-point communications network and is able to withstand common mode disturbance. These advantages make the RS-485 communication interface our choice for changing data format. Star topology is used in this LAN system, where the controller in each resonator and computer on the network connect to the central hub, which then feeds into the computer.

The computer at the highest layer of the network is linked with hubs and responds to reception of experimental data from a capture card, transferring and inserting the data into a database ordered by the address of the experimental device. The computers can efficiently display the experimental results, such that computation and information storage can be completed almost simultaneously. This then gives the teacher the ability to easily monitor the progress and results of student conducted experiments by computer.

B. Data Collection

The software includes two parts. The first is the teaching Management System, which prompts the computer to open an Access database, display data, draw curves, and generate experimental reports. The other part is the SCM software in the controller, which was written in the C programming language. This is based on RTX51, which is a real-time operation system with support for multiple events, numerous tasks, and various methods of inter-task communication.

III. APPLICATION IN LAB COURSES

The experimental physics courses are required at Tongji University for the students whose majors are science and engineering. The students in the physics department have different experimental courses in six semesters, while non-physics students have experimental physics courses in two semesters as General Experimental Physics Ⅰ & Ⅱ (Appendix: Table Ⅰ). Each student will do fifteen experiments and have a chance to choose one open experiment from a list of twenty. It is a challenge to the teachers to give the experimental courses to students on so large a scale, thus making the development of new teaching modes and management methods a necessity.

The experiment with this intelligent resonator network system is set up with second semester students in the engineering departments and the first semester students in the physics department as a way to study the advantage of network-based knowledge.

A. Facilitate the management of experimental-teaching

Software can be used to improve teacher's efficiency and facilitate student management. During the experimentation, the teacher can know the activity of all the experimental devices in the lab, and the experimental progress of each student through a computer. After the course, the students' information can be stored in the computer including their names, numbers, time taken, and results.

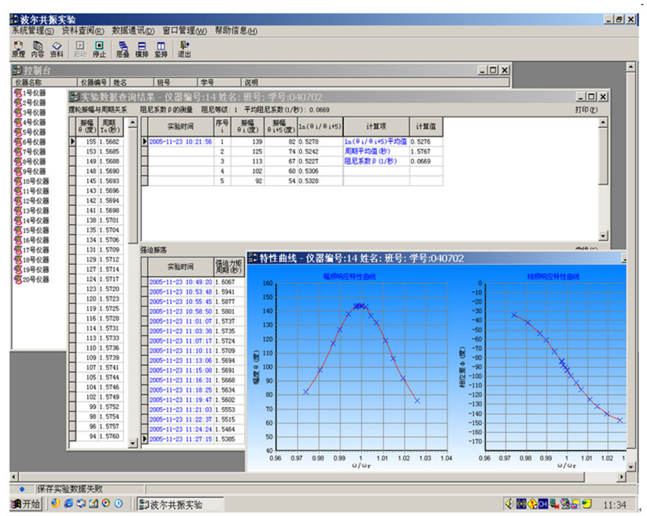

Figure. 2: The data and the curve of the experiment

B. Monitor experimental error under various conditions

After inserting data into the database, we can use the software to compute and query the experimental results of each student, and display them on the screen. For example, the software can compute the damping coefficient of damped oscillation. In forced vibration, it can be used to find the period in the resonance condition based on the amplitude, and then compute theoretical results, such as frequency ratio, amplitude ratio, and phase difference.

There are several methods of error analysis applicable to the experimental data. In free oscillation, the natural period is almost unchanged. In determining the damping coefficient, two or three series of data including the amplitude and time of ten periods can be gathered, with the damping coefficient in each series approximately equal. In forced vibration, theoretical values should be close to computational values of the phase difference, otherwise they can be considered errors.

During the experimental course, teachers can discover errors and ask the students to analyze their mistakes and correct them by themselves.

C. Save and query experiment data

Students' experimental data can be kept in the computer after finishing the experimentation, allowing teachers to query it by the students' name or number, the number of classes, the experimental time, or the instrument number if necessary. The information provided in the records is useful in educational research.

D. Generate the curves of experimentation

After saving experimental data, we can use the software to draw experimental curves (figure 2). The software can also be used to preview and print students' experimental data and curves.

IV. PROSPECTS

The recent advances in computer, information, and network technologies have sparked a vibrant growth of experimental teaching, and it has become a new educational trend to use modern technology. Looking back to the development of experimental physics teaching, we can easily find that the teaching method and mode is constantly updated. The development towards the automatism and networking of experimental physics teaching promotes new teaching modes that conform to the needs of education.

A. Promote the development of computer-assisted education methods

Intelligent physics devices maintain the operation of the entire process for students, allowing it to achieve more functionality than the original device. The modernization of experimental teaching methods helps to accelerate the development of education.

B. Embody the principle of student-centered education

It's easy for students to accept new teaching-models, and master new experimental methods using the device. Intelligent physics network devices can be used to help students do experiments by helping to make the experimental content understandable. The experimental process is visual and easy to learn. It is convenient for students to record large amounts data because of the storage and display of the experimental device. Therefore it can enhance their learning intentions and enthusiasm, as well as promote consciousness, independence, and operational abilities.

C. Improve classroom efficiency

Since the computer monitors the whole experimental process, the teacher is given real-time data on the student's processes and errors, which allows for timely modification of the student's thinking. This increases the effective time for teachers to play a leading role in the limited class time allotted, and improve the quality of their teaching.

D. Convenience in experimental physics course teaching

Computer systems are highly effective in experimental data storage and processing, helping teachers to find errors in the students' experimental results. Furthermore, it is convenient to maintain and update experimental devices by centralized network management. The intelligent physics network system accelerates the modernization of laboratory management, and guarantees the setting and reform of the course system.

Ⅴ. EVALUATION OF THE INSTRUCTION

When the students use the network system in the physics experiment course, they are given a carefully designed research-based survey (10- to 30- minutes) that probes the students' attitudes to this system and teaching method. When we designed the survey, we used the style of the Maryland Physics Expectations (MPEX) (Redish, Saul, & Steinberg, 1998). The survey consists of one question and ten items to which the students are asked to agree or disagree on a 5-point scale, from strongly agree to strongly disagree. In the survey, "A" means strongly agree, and "E" means strongly disagree.

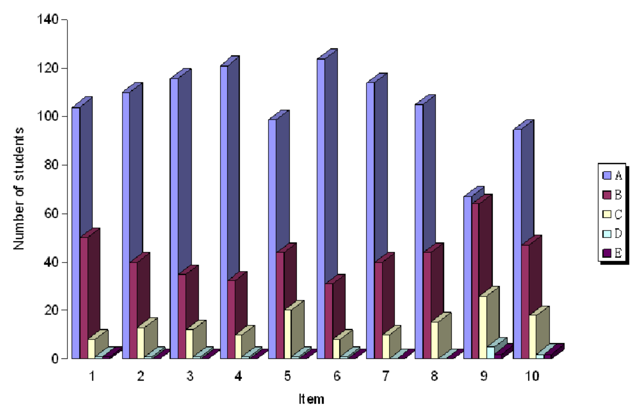

Figure.3 The results of the survey shows the distribution of students who chose different answers.)

We assessed more than 160 students with different majors, including engineering and medicine. Most of the student chose the answers in favor of the system. The question "Do you have any suggestions to improve this network system used in the experimental course?" was asked and many students said that the system was useful for finding mistakes in the measurements, keeping records, and making the results more credible.

IV. CONCLUSIONS

The intelligent resonator network system modernizes teaching, embodies a new thinking in experimental physics teaching, and establishes a brand-new teaching platform. The setting and making of experimental instruments will be further explored based on our research. We hope to develop a series of network experimental systems, in order to enlarge the scale of network teaching management. We are currently developing a laboratory information management platform to realize centralization and increased management efficiency for experimental physics teaching in universities.

It is feasible to build up this new teaching model into practice, so that it is not only accepted and praised by teachers and students, but also widely used in universities and colleges.

ACKNOWLEDGMENTS

We thank the Chengdu Century Scientific Equipment Limited Company for their support and cooperation.

APPENDIX

Table 1. The Survey of Students' Attitude to the Physics Experiment Course with the Network System

	Items	**Attitude**
#1	This experiment helps me to understand the correlative physics concepts deeply.	ABCDE
#2	The teaching materials are helpful to me to understanding the experiment's content.	ABCDE
#3	During the experiment, my abilities in measurement and operating instruments improve.	ABCDE
#4	The teachers' explanations and operation preparations are helpful.	ABCDE
#5	Using the network system, it's effective to check the experiment conditions, find mistakes, and save the data.	ABCDE
#6	With the network system, we can deal with the experiment's data and find the results quickly. It makes the experiment more meaningful.	ABCDE
#7	The operation of the instruments in the network system is convenient to students.	ABCDE
#8	Teaching management with the network system is helpful to me while doing the experiment.	ABCDE
#9	The experiment's instruments are in order.	ABCDE
#10	I find physics and interrelated scientific knowledge more interesting in experimental courses.	ABCDE

Table 2. List of Experiments used in General Experimental Physics I & II.

Measuring the moment of inertia*	Michelson Interferometer
Measuring Young's Elastic Modulus*	Hall Effect
Multimeter	Franck-Hertz Experiment
Measuring the specific heat ratio of air*	Oscillograph Ⅰ
Newton's rings	Oscillograph Ⅱ
Millikan oil-drop experiment	Holography
Resonator experiment*	Measuring wavelength
Measuring sound velocity	Selecting experiments

*Use the Computer Network System

Table 3. Survey Results in terms of the number of students who chose different answers.

	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10
A	104	110	116	121	99	124	114	105	67	95
B	50	40	35	32	44	31	40	44	64	47
C	8	13	12	10	20	8	10	15	26	18
D	1	1	1	1	1	1	0	0	5	2
E	1	0	0	0	0	0	0	0	2	2

ENDNOTES AND REFERENCES:

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