

Research on the Implementation of a Web-Based Effective Remote Experiment System in Distance Education

Chang Myong Ri, Nam Hyok Kim*, Jin Hyok Kim, Kum Chol Jon

Faculty of Distance Education, Kim Chaek University of Technology, 60-Kyogu, Yonggwang Street,
Pyongyang, Democratic People's Republic of Korea

*Corresponding Author

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ABSTRACT

In traditional face to face education, teachers can perform lessons and students do experiments under the teacher's guidance as reflected in the curriculum, but it is difficult for distance education students to perform experiments because of the inadequate conditions for conducting experiments in the curriculum, unlike traditional education. The remote experiment is highly effective because it is possible to conduct experiments while controlling experimental equipment through the network, overcoming the shortcomings of the past when students in distance education were difficult to conduct experiments without having experimental equipments. This paper proposes a solution to the problem of implementing a remote experiment system to provide an experiment that is an important teaching form for improving the practical abilities of students in distance education. In this paper, we have designed the flow of experiment in detail and built a real-time video conversation using WebRTC technology to provide instructor guidance and team interaction during the remote experiments, and we have described a method for implementing web-based experimental equipment control and monitoring without need of installing any software.

Keywords: Distance education, Remote Experiment, Remote Lab, Control Engineering, Embedded System

INTRODUCTION

The practical activities play an important role in science education [1]. In the traditional face to face education, students are assigned the subject of the experiment according to their subject course, and the experiment is conducted. Students come to the labs built at the university and face the equipment directly and do the experiments under the guidance of the teacher. But in distance education, it is very difficult to solve this problem because students have to do experiments at experimental sites in order to perform this type of experiments, which differ in the lecture progress and, importantly, in the geographic distance of learning. In distance education, a remote experiment is established and education is provided to overcome the limitations of experimental education and enhance the creative ability of students. The remote experiment is the one in which students operate the experimental equipment remotely through a computer network and at any time according to their experimental design. In other words, it is an experiment that is conducted without restriction of the experimental time and equipment, without having to go to the laboratory equipped with the experimental equipment. The remote experiment can solve the problems that have been raised in relation to practical education in the distance education. This paper presents a proposal for distance education to enable students to conduct remote experiments that can directly control the experiment equipment through the network and simultaneously discuss the interaction between the team members while instructor's guidance, and then to address the challenges of implementing it.

BACKGROUND

Remote Experiment

In the previous literature, the remote experiments were divided into three types.

First, in a form that only obtains the input and the corresponding output for the remote-controlled experimental setup, the experimenter can only collect data on the experimental values.

Second, as a form of experiment, the experimenter can change the value of the control parameter of the remote experimental equipment and obtain the corresponding operating condition and output value of the equipment.

Third, the control program of the remote experimental setup and the control parameter values are changed, which is the type in which the experimenter performs the experiments according to his intention.

Previous studies have provided remote experiments by implementing solutions via Web or custom interfaces according to these three types.

Several examples of remote experiments are available.

In [2], LabVIEW was used to implement experiments on speed control of motors. A system was designed and implemented to realize the speed control characteristic parameter setting and the corresponding speed control method of the motor. Monitoring was achieved using a dedicated IP camera monitor.

In [3], Raspberry PI was used to implement a system in which students can remotely control the experimental setup using a portable terminal.

In [7], a study on the aspects of accessibility and usability for remote experiments is presented and a study on remote equipment access using a web browser is presented.

In [9], the authors propose a system that allows students to perform experiments using smartphones or mobile terminals, while the authors propose a problem of implementing remote experiments using mobile devices.

In [8], a method of conducting experiments and connecting remote to a computer directly connected to a remote-control facility using VNC is described.

Several examples of the implementation of the remote experiment can be found in common.

First, a test rig for conducting remote experiments was designed to allow the network to be controlled and to share the experimental values to the experimenter.

Next, monitoring of the operating conditions of the experimental setup can be performed.

WebRTC

The advantage of WebRTC technology is that it enables real-time voice, video and data communication without the need to install other plug-ins between browsers [11]. The architecture of WebRTC technology is shown in Fig. 1. Several examples of WebRTC technology implemented in distance education are presented.

In [10,11], we describe how to use WebRTC technology to deliver real-time lectures and conferences. This technology allows real-time video conversation and data transfer between instructors, students, and students, so that free communication can be achieved during the experiment.

The problems that have not been solved in the previous remote experiment are the independent, interactive interactions between the teacher and student, and between the members of the experimental group, which is not sufficient to ensure the effectiveness of the experiment and the inability of the experimenter to perform the experiment properly if the experimenter is unaware of the experimental process. And another problem is to setup additional plugins.

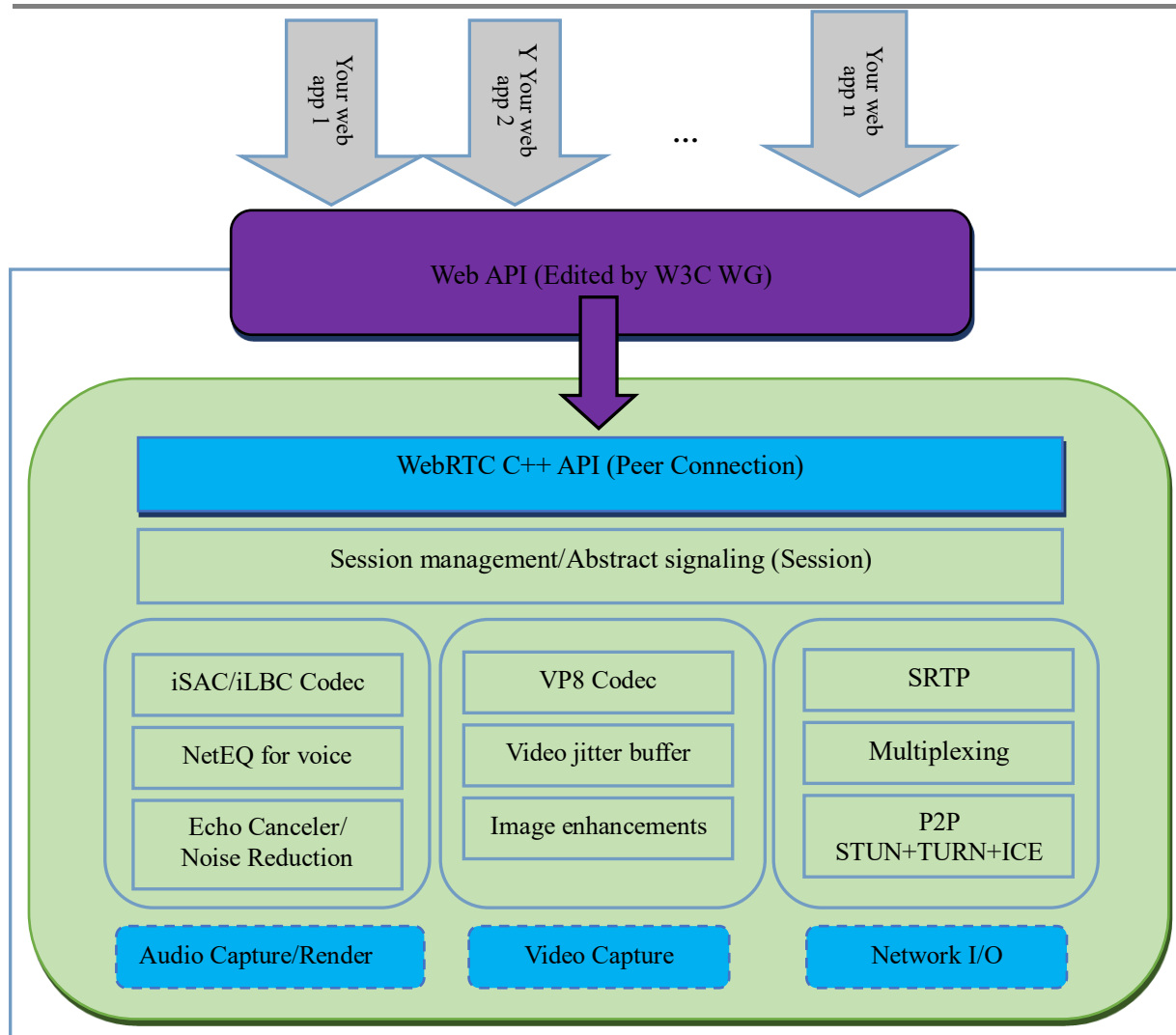


Fig. 1. Architecture of WebRTC

System Design

The main features of the remote experiment can be summarized as follows.

First, students do the experiments through the network without going to the laboratory where the experiment equipment is available.

Second, the remote experimental resources are open to students and available to students without any limitation.

Third, the experimental time can be chosen freely.

Of course, there is a limited number of experiment equipment and time choices in cases where students are in need, but this can be achieved by making reservations and experimenting at the time of the experiment in relation to the use of the laboratory equipment.

From the characteristics of the remote experiment, the problem to be solved in the design is chosen as follows.

- The experimental process through the remote experiment should be designed correctly.
- It should be possible to perform remote experiments through web pages without having to install other software or plugins.
- Students should be able to monitor the experiment equipment in real time.
- For one experiment equipment, only one right to control is available at the any time.
- The teacher's guidance and student's inter-discussion should be provided during the experiment.

Flow

The flow of the remote experiment was designed as shown in Fig. 2.

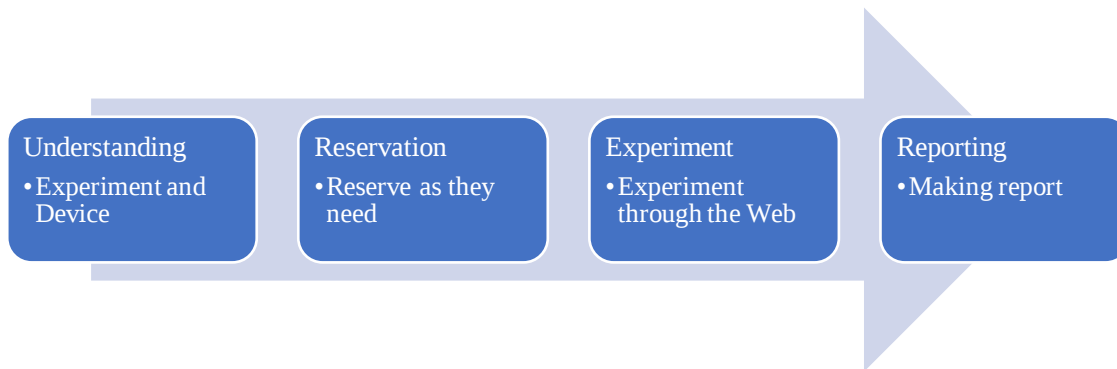


Fig. 2. The flow of proposed experiment

As shown in Fig. 2, the process of conducting the experiment was designed as follows: Students were asked to examine the experiments before they were able to perform the experiments. The purpose and principles of the experiment, the method of the experiment, the procedure of the experiment, etc. are discussed in detail. After the experiment is understood, the equipment used in the experiment is analyzed. Understand the use of the test rig, the configuration of the equipment, the operating principle, etc. Then, students make a reservation for the equipment to perform a remote experiment. For one experimental setup, several experimenters cannot control simultaneously, so the equipment reservation is done. The instructor organizes the experimental group according to the state of the equipment reservation. Then, students conducted the experiments in groups and made the experimental report. The students can be encouraged to have a real-time dialogue between the instructor, students and students during the experiment, thus providing guidance and discussion of the experiments.

Software Design

Web Program Design

The web programming phase is designed to monitor the operation of the equipment through a web browser, control the experimental equipment, and enable real-time teaching and discussion between the instructor and the student and between the students. Figure 3 shows a schematic of the implemented web program.

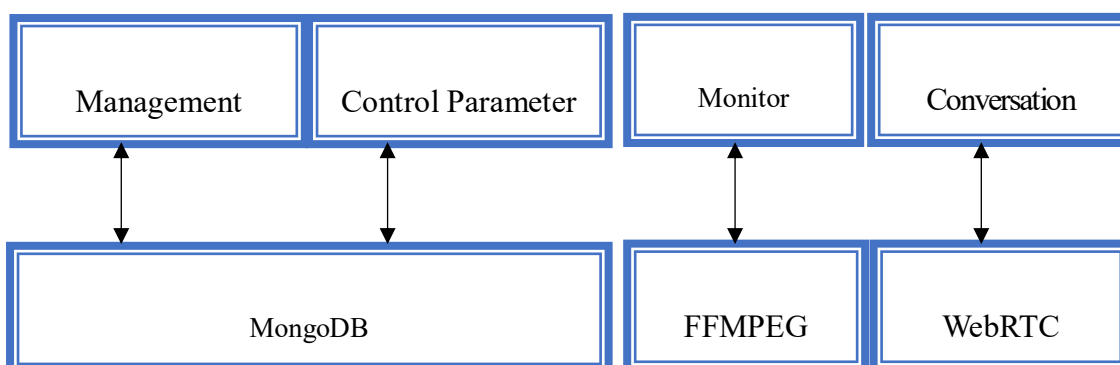


Fig. 3. The architecture of Web program

Design of Main Function

-Monitor

In order to catch the equipment state through browser, we designed this function. We use IP camera (Hikvision) to get real-time state of equipment. Students can watch the equipment state while performing the experiments

and directly observe the operating conditions of the equipment according to the control parameters when performing the control remotely.

-Control

It is a key function to perform experiments by varying the control parameters of the experimental equipment through the web page. The experimental equipment control function is a function of receiving the value of the equipment control parameter, stored in the database, and then transferred on request to the equipment control program via REST API.

-Real-time teacher guidance and team interaction

This function provides the teaching and discussion between the teacher and student, and the student each other. We designed the video chatting and text conversation functions.

Design of Web Page

-Experiment investigation page: browse the details of the experiment you want to perform. The following topics are explored: experimental purpose, experimental principles, experimental equipment and experimental procedure.

-Equipment investigation page: browse the details of the equipment used in the experiment. The equipment shall be searched for its use, technical characteristics, standard operating method, precautions, photographs of equipment and video of equipment.

-Reservation page: reservation is made for a particular equipment. Set the date, start time and finish time.

-Experiment page: The experiment is conducted by remotely controlling the equipment through a homepage.

-Report page: Based on the experiment, a report is generated by students.

The following are designed as pages for the management of the remote experiment:

-Experiment management page: administer data that students can understand the experiment.

-Equipment management page: administer data about the equipment.

-Reservation management page: The equipment reservation management is performed. The details were selected as equipment subscribers, subscription experiment scheme, subscription equipment, start-up time, completion time, etc.

-Group management page: Five students were selected for each appointment time, and the experimental group was composed of the group.

-Report management page: Evaluation and management of the laboratory report written by the students.

-Equipment control authority management page: Once the experimental group is organized, automatically the equipment control authority is granted only to the leader of experiment group, and the leader can transfer the authority to any team member. Only the user with control authority can control the equipment.

Design of Equipment control Program

The equipment control program was designed to allow students to control the actual device, by entering equipment control parameters through a web page, sending the value to the device, and returning the current measurement value of the device back to the student. The control parameter values that the student entered on the web page were transferred to the equipment control program via the REST API and designed to implement the control accordingly. The device's measurement values were also designed to be transferred to the web page via the REST API.

In the design of the equipment control program, we divided it into a web page interface and a hardware interface (Fig. 4).

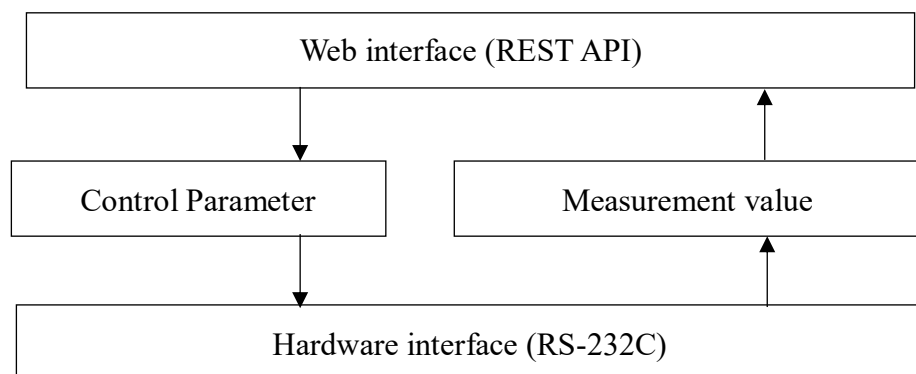


Fig. 4. Design of equipment control program

Hardware Design

The hardware design phase allows students to experiment with various controllers and devices directly.

Five types of experiments were conducted: motor speed control experiments, level control experiments, temperature control experiments, sequence control experiments, and embedded system experiments.

Controller

Different controllers were selected according to the experimental setup to design the experimental setup.

PIC16F877A, STM32F415 and Arduino UNO were used to help students deepen their understanding of the devices using different types of controllers.

Other Devices

- Sensors: Encoders were used for speed measurements of motors. In addition, the ultrasonic sensor was used for level control. PT-100 was used as a sensor for temperature measurement of the heating furnace.

-Display: A 7-piece LED and LED panel (16 x 64) were used.

By designing the above remote experiment, it is possible to realize an experimental system that can remotely control the experimental setup, monitor and measure the results, while combining real-time lectures and discussions between instructors, students and students through web pages.

Implementation

We developed the homepage as node.js.

MongoDB database was used to manage all the data needed. The real-time and real-time video interaction between students and teachers were implemented using WebRTC technology.

The camera image of the device was realized by collecting photos in real time using ffmpeg and displaying them on a web page to allow monitoring without the need for additional plug-in in on the web browsers. An equipment control program was created to transfer the setting parameter values and measurements using the REST API.

Five types of experimental equipment have been developed.

Temperature control, level control and sequential control were developed using PIC16F877A, speed control using Arduino UNO, and an embedded system software experiment was developed using STM32.

The communication between the device and the control computer used RS-232C communication.

CONCLUSION

The remote experiment is very important for improving the practical ability of students in distance education. This paper presents the issues of the implementation of a remote experiment. The system was implemented to enable students to control and monitor equipment remotely through a Web, and real-time text and video conversation between students and teachers was achieved using WebRTC technology. In the future, a generalized model for remote control of various equipment should be developed and developed to contribute to improving students' practical abilities.

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DATA AVAILABILITY The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

DECLARATIONS

Conflict of interest Authors declare that they have no conflict of interest.

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