

A Novel Wiki-Based Remote Laboratory Platform for Engineering Education

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Abstract—With the unprecedented growth of e-learning, more and more new IT technologies are used to develop e-learning tools. As one of the most common forms of social computing, Wiki technology has been used to develop the collaborative and cooperative learning platform to support multiple users learning online effectively. In this paper, we propose a new software architecture to create a novel wiki-based remote laboratory platform by combining the advantages of both Wiki technology and remote laboratory technology. This platform is implemented based on a unified framework for remote laboratory development and an open source wiki software package, MediaWiki. To illustrate the effectiveness of this platform, two remote experiments, Smart Vibration Platform (SVP) and Proportional-Integral-Derivative (PID) motor speed control, are integrated into this platform. This new wiki-based remote laboratory has been used for teaching Mechanical Engineering courses and creating students' assignments at the University of Houston.

Index Terms—Remote laboratory, wiki technology, unified framework, learning technology, online learning

1 INTRODUCTION

INFORMATION technology has had a great impact on education by providing additional teaching and learning strategies such as online learning. According to the 2015 Sloan Survey of Online Learning [1], the number of students taking at least one distance course is about 5.8 million in fall 2014; meanwhile, the number of students not taking any distance education courses continues to drop. As the student is the center of any learning service, online course offerings must provide a unique value to maintain a high-quality education instead of simply repackaging content designed for traditional face-to-face learning environments. To provide unique advantages for student-centered learning, Wiki technology was proposed to create a collaborative learning environment [2]. Wiki technology, which is one of the most common forms of social computing, allows multiple users to collaborate and cooperate in generating and customizing knowledge in a user-friendly editing environment. As the name implies, Wikipedia is a prime example of a collaborative environment allowing users to create an encyclopedia using Wiki technology. Supported by the wiki engine and run by wiki software, a wiki allows users to edit a page or create a page of

knowledge inside the wiki. In most cases, most of the editing can be done directly through a web browser without additional plug-ins or strong programming skills. The ease of use along with the wiki's intrinsic advantages as a combined knowledge manager and social platform is essential to creating a collaborative learning environment. Another benefit of a wiki-based learning environment is that the wiki can provide a much stronger social context that is lacking in the current state of online courses. The advantages of collaboration provided by the Wiki technology has shown to strengthen the building of social ties, development of constructive peer critiquing skills, and other essential social skills [3], [4], [5]. With Wiki technology serving as the stage for learning, students and instructors may easily collaborate and communicate. In the long term, they can also co-design the structure and direction of a course through a co-create knowledge process. Thus compared to most current social environments (e.g., face to face and online), wikis are able to add an extra collaborative and active learning dimension that greatly encourages a collectivist effort among students and instructors to construct new knowledge [6], [7].

As an important component of online learning, the remote laboratory technology also has made great progress. The concept of a remote laboratory implies the use of Internet and system control technologies to remotely conduct real-time experiments. Because of the effectiveness, flexibility and cost-savings of a remote laboratory, many applications are being recognized in Science, Technology, Engineering and Math (STEM) education. Remote laboratories can be highly effective tools in helping a wider range of students, regardless of geographical restrictions, to obtain practical experience need for competency in science and engineering [8]. This location-independent access is especially useful in scenarios where space is limited, or for distance education [9]. The concept of a remote laboratory itself has been around

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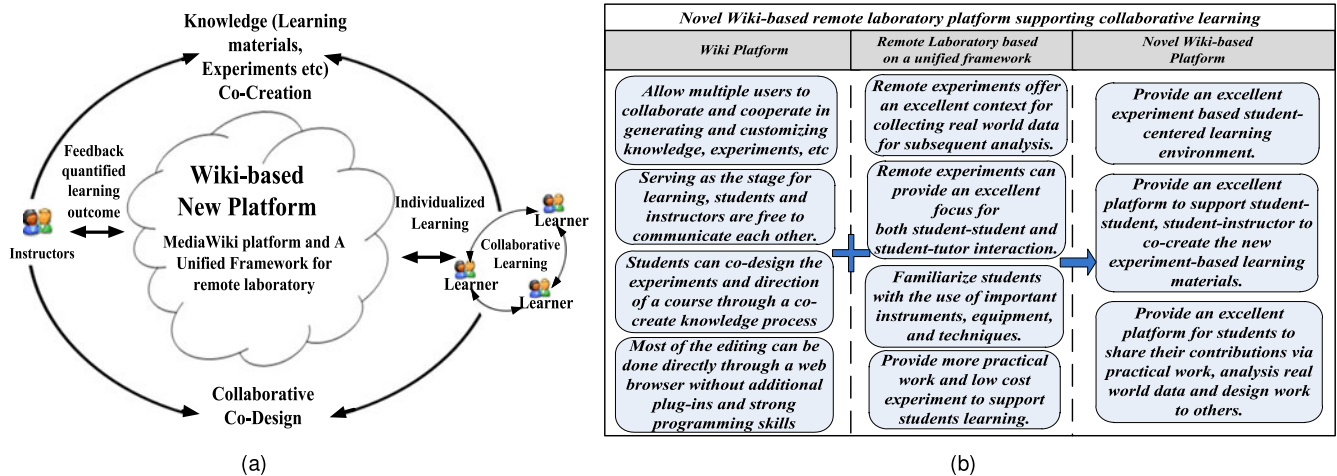


Fig. 1. (a) A novel wiki-based collaborative online learning environment with remote laboratory. (b) Advantages of the novel wiki-based platform.

since the introduction of the Internet in the 1970s, and has slowly evolved from the union of online-learning programs, such as MIT Open-Course-Ware, PROLEARN, etc. and with distance laboratory efforts around the world [10], [11]. Most early stage remote laboratories relied on the Client-Server architecture for achieving high-performance real time experimental data transmission [12], [13]. Examples include the remote panel provided by the National Instrument's LabVIEW (Laboratory Virtual Instrument Engineering Workbench) [14], a digital-signal-processor-based remote control laboratory at University of Maribor [15], the Distance Internet-Based Embedded System Experimental Laboratory (DIESEL) at the University of Ulster [16] and others. Later on, Client-Server architecture based on Web services and .NET remote services were developed and deployed for remote laboratories [17]. With continuing improvements to computer performance, the technology supporting the Browser-Server architecture is becoming increasingly more stable and suitable for cross-platform system design. The importance of adopting cutting edge web-related technologies, Web 2.0 and Web Services/Service Oriented Architecture (SOA), to produce better remote laboratories is addressed. Meanwhile, a large number of new technologies (such as Java applets, Adobe Flash, AJAX, HTML, ActiveX, etc.) have been developed to support more complex web browser-based Internet applications. Consequently, more and more remote laboratory software systems have selected web services technology and SOA architecture to implement the Browser-Server architecture remote laboratory [18], [19]. The remote laboratories based on Web Services technology and SOA architecture include MIT iLab [20], WebLab-Deusto [21], the Networked Control System Laboratory (NCSLab) [22], the improved NCSLab 3-D [23], the eComLab at UTSA [24]. As it was pointed out in [18], [19], [25], most of improved remote laboratory solutions mainly focus on the technology innovation, such as software and hardware platform upgrade, use of new IT technology. Developing a well-structured and coordinated online learning platform to improve engineering education becomes an essential issue [26].

To address aforementioned issues, we propose a novel wiki-based remote laboratory learning platform as shown in Fig. 1a to utilize advantages of the Wiki technology and remote laboratory technology for engineering online

education. Based on this novel learning environment, a collaborative and cooperative remote laboratory platform is created. Fig. 1b depicts the advantages of the novel wiki-based remote laboratory learning platform. To the best of our knowledge, this is the first remote laboratory to present the remote experiment with a collaborative and cooperative learning environment. Integration with Wiki technology is an essential improvement for remote laboratory development in future. Through this novel learning environment supported by remote laboratory technology, students and instructors can collaboratively design and implement new experiments to support student-centered engineering online learning more effectively.

The rest of the paper is organized as follows. A unified framework for remote laboratory development and the Wiki technology for collaborative learning are presented in Section 2. In Section 3, the detail architecture of the novel wiki-based remote laboratory platform is presented. In Section 4, the implementation of new platform is described. The future works are summarized in Section 5. Concluding remarks are drawn in Section 6.

2 PREVIOUS WORK

In this research, the biggest challenge is how to create a new architecture to seamlessly integrate the remote laboratory into the Wiki platform. The prior unified framework proposed by the authors solved several critical issues including the ability to provide real-time video and real-time data transmission without software plugins and firewall issues [27], [28], [29]. In order to further build upon the advantages of the unified framework with Wiki technology, an efficient and stable wiki engine must be selected as a foundational platform. Thus, our previous work on unified framework and wiki based collaborative learning system are summarized in this section. The process of selecting a suitable wiki engine is also briefly described.

2.1 A Unified Framework for Remote Laboratory Development

A number of currently available solutions use Web 2.0 and Web Services/Service Oriented Architecture technology to produce the quality remote laboratories without software plugins [18], [25]. However, the main drawback of Web

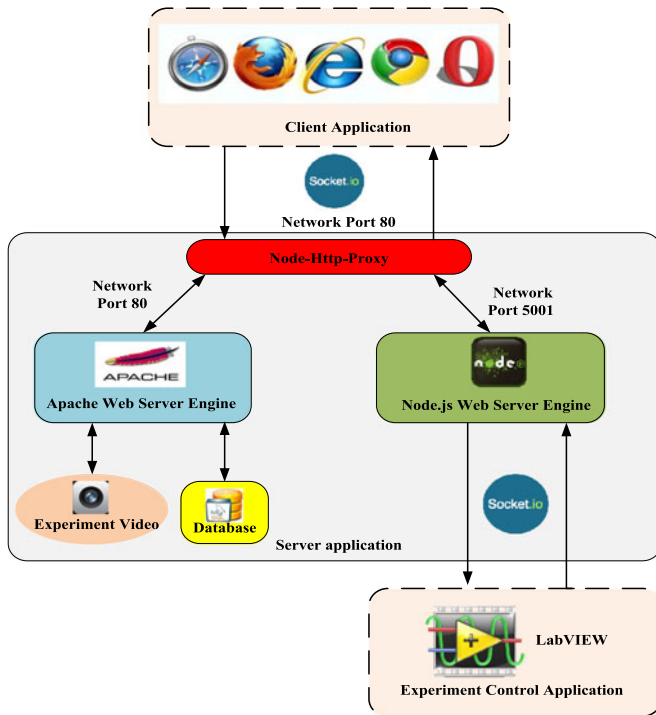


Fig. 2. The architecture of the unified framework [27].

Services is the performance. Non-HTTP-based technologies tend to be faster than Web Services, and speed is important in real-time communication between the experiment and end users [18], [19].

Our previous work mainly focused on the fundamental design and development of a unified framework [27]. The subsequent iteration of the design resolved several challenges of developing cross-browser and cross-device web user interface as an improvement to the unified framework [28], [29]. The system architecture of the unified framework is shown in Fig. 2. This unified framework is based on the Web 2.0 technology and includes three parts: client web application, server application, and experiment control application.

- 1) *Client web application*: The client web application runs on most of current popular browsers, and is based on HyperText Markup Language (HTML), Cascading Style Sheets (CSS), and JQuery/JQuery-Mobile JavaScript libraries. Further, it uses the server-based mashup technology for User Interface (UI) implementation.
- 2) *Server application*: In order to resolve the web services technology performance issue for the server application implementation, a combined solution of both Apache web engine and Node.js web engine was implemented for the real-time communication between experiment hardware and end users. Node.js is a free-ware package for server-side application development, and contains a built-in HTTP server library. Thus, it allows more control of the web server by making it possible to run a web server without the use of external software, such as Apache or Microsoft IIS [30]. Node.js also enables web developers to create an entire web application in JavaScript which are both server-side and browser-side. In the Node.js server-

TABLE 1
Technology/Protocol/Software List of the Unified Framework

Name	Technology/ Protocol/ Software	Remark
1. <i>HTTP Proxy</i>	Node-HTTP-Proxy	Part of Node.js
2. <i>Communication Protocol</i>	Socket.IO	Part of Node.js
3. <i>Real-time experiment video Transmission</i>	Http Live Streaming Protocol /FFMPEG/ Segmenter software package	
4. <i>Database</i>	MySQL	
5. <i>Client-User Interface</i>	Mashup technology, JavaScript	
6. <i>Server-Web Service</i>	Apache, Node.js, JSON	LtoN (LabVIEW to Node.js)
7. <i>Equipment Control</i>	LabVIEW	

side software system, Socket.IO, a JavaScript library for real-time web applications, is used to support real-time communication between server side and client side [31], [32]. Thus, the server application is based on Web Service technology and is directly built on the top of a MySQL database, an Apache web server engine, and a Node.js web server engine. Meanwhile, the Operation System (OS) of the server uses Centos 6.7 OS to better support the server application.

- 3) *Experiment control application*: The experiment control application was developed with LabVIEW, and ran on a workstation with Windows OS. The new LtoN (LabVIEW to Node.js) protocol was used to implement the real-time communication between the experiment equipment and server application. The new LtoN protocol was designed and implemented based on Socket.IO protocol.

Table 1 depicts the technical characteristics of the unified framework for remote laboratory development in detail. For the entire framework, three vital technologies were used in this implementation. These technologies include: a) Socket.IO protocol and Node-HTTP-Proxy used for experiment data and control commands transmission and traversing firewall; b) a novel video transmission approach was developed based on HLS protocol for real-time system monitoring; and c) the server-based mashup technology was used for user interface implementation. This unified framework has been used to implement several remote control experiments for engineering education. For example, the new Smart Vibration Platform (SVP) remote experiment is now used to teach students in mechanical engineering courses at the University of Houston (UH). The SVP offered students hands-on experience on structural vibration control by using a Magneto-Rheological (MR) and Shape Memory Alloy (SMA) braces to control the vibration of a one story model structure [33].

2.2 Wiki Technology for Learning System

Wiki technology has been used in the academic community for sharing and dissemination of information across institutional and international boundaries. In those settings, they have been found useful for collaboration on grant writing, strategic planning, departmental documentation, Authorized licensed use limited to: IEEE Xplore. Downloaded on October 19, 2024 at 19:03:22 UTC from IEEE Xplore. Restrictions apply.

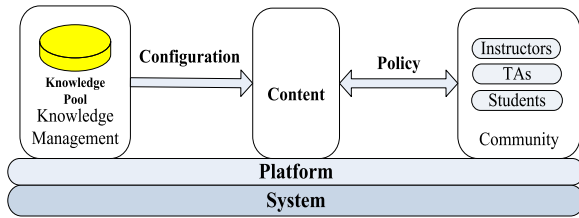


Fig. 3. Wiki technology for learning construction relationship.

and committee work. In the mid-2000s, the increasing trend amongst industries toward collaboration was placing a heavier impetus upon educators to make students proficient in collaborative work, inspiring even greater interest in wiki being used in the classroom. Fig. 3 shows the relationship of the wiki construction we proposed for better integration in the learning system for use in the classroom.

- 1) *System*: System is the software architecture of Wiki platform. Currently, the most popular and stable system architecture which is used for Wiki technology is the LAMP (Linux, Apache, MySQL, and PHP) architecture. It includes four factors, Operation System (Linux), Web server software (Apache HTTP server), Database system (MySQL), and Server-side scripting language (PHP stands for Hypertext Preprocessor).
- 2) *Platform*: The platform includes the software development framework, development language, etc. The platform supports communication, user interactions, and knowledge sharing between the communities with knowledge management module. Normally, there are several modules in the platform, such as system configuration, user management, content management, task management, etc. It was developed by PHP language and run on the LAMP system.
- 3) *Knowledge pool*: Knowledge pool is the data storage and management tool. It is the core of the whole knowledge management module. All of the knowledge contents, such as ebooks, lectures, papers, discussion contents, and other needed materials, are saved in the knowledge pool database.
- 4) *Content*: The content is the operation object by the members of the community and knowledge management module. The mainly operations for content are adding, deleting, searching, modification, updating, etc., and the content mainly includes books, papers, discussion contents, teaching plans, and other teaching materials. The content module is the user interface in the wiki, and is consisted of many web pages which also are developed by PHP language.
- 5) *Community*: the community mainly includes professors, teaching assistants, and students. Meanwhile, it also can serve other persons who want to obtain the knowledge from this system and is granted accessing authority from the system.
- 6) *Configuration*: This aspect of the system selects knowledge management tools to organize and manage the materials between the knowledge management system and the content.
- 7) *Policy*: Policy is the rule for editing and managing the wiki platform. In order to keep the coherence of the content operation, as the members of the community provide or modify the content, they must follow the

rules which are established for the whole platform. The institute may have some management policies like the format of the web pages, the font and the size of words, the coherence of the terms to order the content which make sure the quality of the information. Then it helps to search and modify the information more easily.

For an efficient and stable wiki system, the selection of a foundational platform is important. An easy to use, high performance and stable software wiki engine is the foundation of a successful wiki system. Currently, the most successful wiki platform application is Wikipedia (https://en.wikipedia.org/wiki/Main_Page). The open-source software package, MediaWiki, is the software engine of Wikipedia. The MediaWiki provided a complete set of foundational modules and Application Programming Interfaces (APIs). As the MediaWiki provides various functional standard extensions [34], the unified framework can be integrated into MediaWiki to establish a novel wiki-based remote laboratory platform. Meanwhile, students can co-create the new remote experiment-based learning materials with others without strong programming skills by using a simple script language, namely MediaWiki semantic language [35]. Based on the strong social media functions of MediaWiki platform, such as, chat room, search engine, blog, etc., the new wiki-based platform can also provide the strong communication and cooperation capability for creating a better student learning environment. This is a significant improvement on the traditional remote laboratory platform. With combination of remote laboratory technology and Wiki technology, the novel wiki-based remote laboratory platform can provide more powerful functions to support engineering education.

3 THE PROPOSED ARCHITECTURE

To seamlessly integrate the unified framework into the Wiki platform, a Wiki-based Remote Laboratory Platform Architecture (WRLPA) is proposed to implement a novel wiki-based remote laboratory platform. A schematic of the WRLPA is shown in Fig. 4. To provide an excellent student-center learning platform, three layers of software development will be implemented: a) the Database layer, b) the Platform layer, and c) the Client layer. At the bottom layer, the database layer includes a Data Pool (DP), which contains all the information such as, learning materials, experiment data, student performance records, student blog, communication records, etc. This layer mainly provides data storage, data retrieval and query to support platform layer. In the middle layer, the platform layer, which is the core of the novel wiki-based remote laboratory platform, consists of the following modules: a Study Aids Module (SAM), a Remote Experiments Management Module (REMM), a System Management Module (SMM), a User Management Module (UMM) and an Appending Module. The SAM, REMM and SMM work together to provide some new key functions of the novel remote laboratory platform to support the student-center collaborative and cooperative learning. The Appending Module (AM) mainly provides a social context for students learning. It means that students can communicate with others, search some learning materials, and search new remote experiments via this module. The UMM provides the user management functions to support the normal usage of the systems. On the top is the

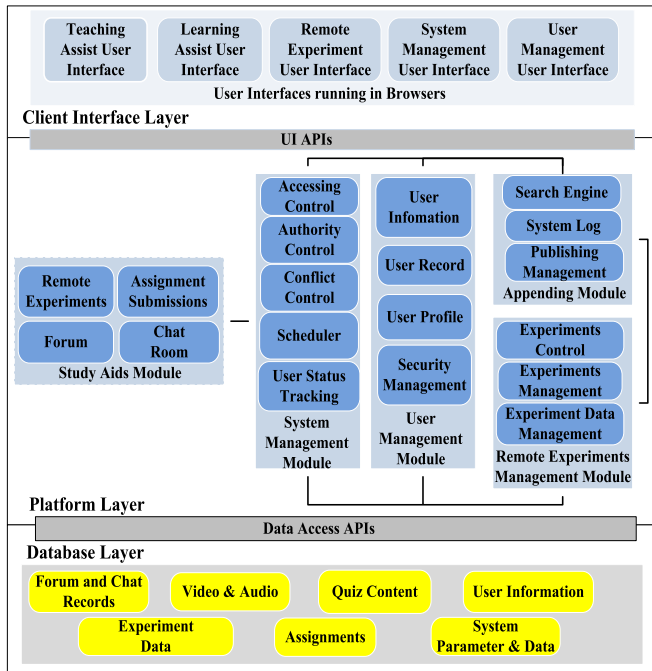


Fig. 4. The architecture of wiki-based remote laboratory platform.

client layer which includes different user interfaces to be supported by a set of User Interface Application Programming Interfaces (UI APIs) that help the user interact with the platform. This layer can provide friendly user interface for students to support their different learning activities.

To achieve the goal of cross-platform deployment, the novel wiki-based remote laboratory platform is implemented by Hypertext Preprocessor (PHP) language and JavaScript language. These two general-purpose scripting languages which are especially suitable for server-side web development will be runs on a LANMP web server. The detailed descriptions of these three layers as follows.

3.1 Client Layer

In the client layer, there are mainly three different kinds of applications (i.e., teaching applications, learning applications and system management applications) to support student-center collaborative and cooperative learning for three different user groups (i.e., students, instructors, and system administrator). The users can create new contents (new remote experiments) easily by interfacing with the client layer. The different users may choose different styles of user interface and users are assigned different levels of authority to use the novel wiki-based remote laboratory platform. The different users can only edit their own learning materials. As co-creating the remote experiment based learning or teaching materials is the core new function of this novel learning platform, students can work with their fellow students to generate some creative remote experiments to support their learning. For the client layer design, the interface, logic and content separation design pattern are used to ensure ease of maintenance and upgrading. An adapter API layer for data exchange is needed for communication between the platform and client layer. Socket.IO protocol will be used to implement the real-time experiment data transmission between the user interface layer and the platform layer. Meanwhile, the Simple Object

Access Protocol (SOAP) also is used to implement the other data (such as assignments data, quiz data, etc.,) transmission between the user interface layer and the platform layer. Data are saved in Extensible Markup Language (XML) format file for transmission.

3.2 Platform Layer

In the platform layer, there are two core modules, REMM and SAM. The SAM, REMM and SMM work together to provide key new functions of the novel platform to users, such as co-creation of a new remote experiment, generation of a new experiment-based teaching or learning material, creation of a cooperative remote experiment for a group of students, etc. As shown in Fig. 5, there are five modules and around 40 sub modules need to be implemented and integrated.

The REMM, which is based on a unified framework, is one of the critical modules in the platform layer. It is used to control and manage all of the remote experiments. The REMM can deliver many services, such as the ability to conduct remote experiment, view experiment videos, manage and analyze experiment data, edit the experiment tutorials, etc., for students to support their collaborative online learning and co-creation with instructors. Meanwhile, it also can deliver services such as creating a new remote experiment, editing remote experiment, posting the experiment tutorials, etc., for instructors to support their teaching and co-creation with students. In the REMM, all of the remote experiments will be shown as web pages in the web browsers without requiring any software plug-ins. Currently, we have developed several remote experiments including Smart Vibration Platform experiment [33], Smart Memory Alloy experiment [36], and Proportional-Derivative-Integral (PID) motor speed control experiment [37]. These remote experiments can demonstrate many concepts and phenomena in dynamics and controls. For example, if a student has difficulty in understanding the effect of stiffness of a dynamic system on its fundamental natural frequency, the remote SVP can vividly reveal this relationship experimentally.

The SAM is the other critical module in the platform layer used to organize, manage, and maintain all of the learning materials and the remote experiments delivered by the REMM. The SAM is the key module which supports the co-design of experiments and co-creation of knowledge between instructors and students. The SAM is also an online learning tool and can deliver many services, such as the ability to create new materials, edit materials, search materials and remote experiments, do homework online, post to a discussion board, etc., for students to support their learning experience. Meanwhile, the SAM enables instructional services, such as creating new pages, editing (add and delete) lectures, posting homework, etc., for instructors to support their teaching. In the SAM, all of the materials also are shown as web pages in the web browsers. Users can create and edit the pages of SAM in markup language which allows the SAM to function as a cross platform online learning tool. Users can edit SAM content by following the user policy. The policy consists of management policies, such as the format of the web pages, the font and the size of words, the coherence of the terms to organize the content, and guidelines regarding the quality of information. Operation requests are considered as user requests to perform certain tasks, such as search, edit, create, post,

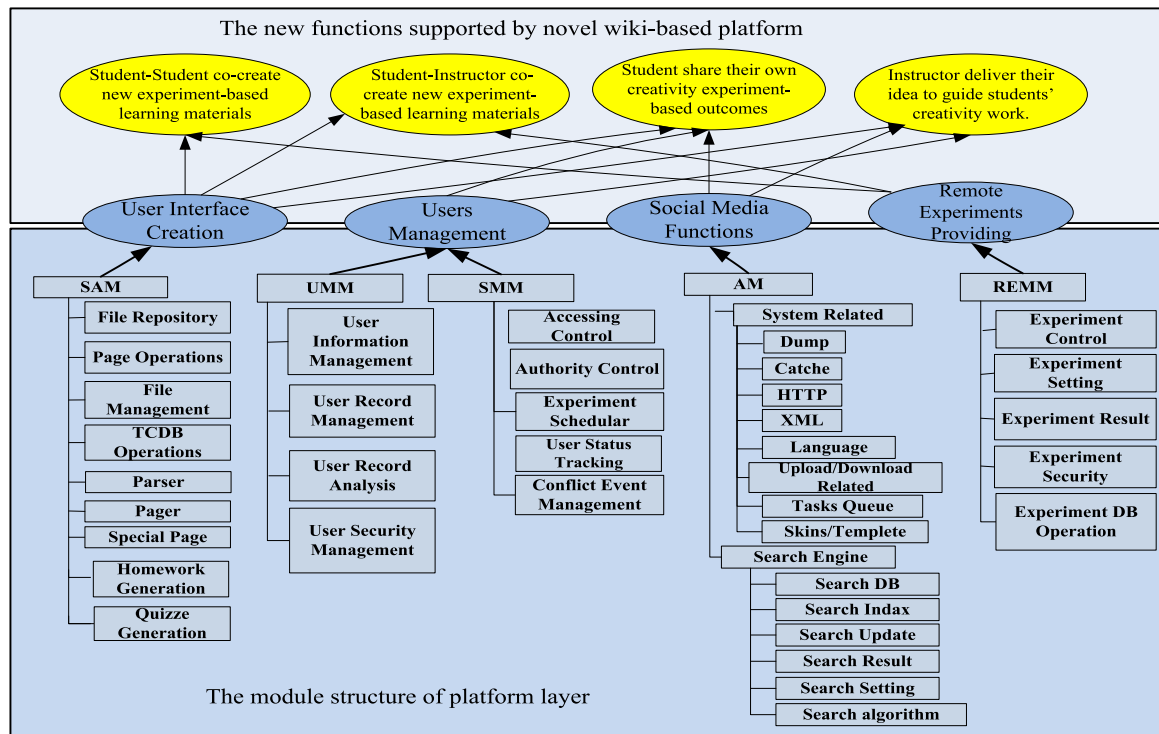


Fig. 5. The module structure of platform layer in the novel wiki-based remote laboratory platform.

upload, download, etc. The selected content is in the client layer and supported by the platform layer. The novel wiki-based remote laboratory platform integrates these implemented remote experiments to further address the different learning needs of students.

The novel integration of REMM and SAM delivers a student-center collaborative and cooperative learning environment where students can put their learned skills to practice while improving their understanding of course concepts. By providing an outlet to address visual and kinesthetic learners through a web environment, the learning needs of students can be fulfilled. Based on the function and logic design for the platform layer, the functional modules are divided into two categories. a) Database operation modules: these modules are used to deliver the APIs to support the database operations (such as query, add, delete, modify, save, view, etc.). b) Supporting development modules: these modules are used to deliver the APIs to support other layer development. The object oriented programming (OOP) approach is used to define the classes and functions. Meanwhile, PHP language and JavaScript language are used to implement all of the classes and functions.

3.3 Database Layer

The core of the database layer is the data resources development, which includes development and integration of a set of databases to support the operation of the platform layer. Particularly, three kinds of databases need to be developed and integrated – the study aids databases, the system databases and the experiment management databases – in order to support the proposed wiki-based remote laboratory platform. For the implementation of database layer, the most important task is to design and develop the Data Pool. Some databases need to be developed and integrated (including the search database, user information database,

experiment database, page database, file database and system parameters database, etc.) to the Data Pool. There are a total of 78 data tables implemented for the Data Pool.

4 IMPLEMENTATION OF THE NOVEL PLATFORM

The method about how to combine the unified framework and MediaWiki together to generate the novel wiki-based remote laboratory platform is shown in Fig. 6. The system architecture of MediaWiki is shown in Fig. 6a. As the fundamental platform, the MediaWiki includes three layers, user interface layer, system logic layer and data management layer. The webserver of MediaWiki uses the Apache. In Fig. 6b, the unified framework is integrated into three parts, a) web server is changed to Apache and Node.js combined solution (in the red square), b) remote experiment data is integrated into the database of the new Wiki-based remote laboratory platform (in the red square), c) components which are used to support remote experiments are integrated into the new Wiki-based remote laboratory platform (in the blue square). The implementation process of novel wiki-based remote laboratory platform mainly includes two steps. In the first step, the fundamental environment, MediaWiki, is installed to provide the basics systems APIs and development environment for the next step implementation. In the second step, the five modules and about 40 sub modules shown in Fig. 5 will be implemented and integrated into the fundamental environment. Meanwhile, around 78 data tables will be implemented for the Data Pool in this step also. The detailed implementation process is as follows.

4.1 The Implementation Process of New Remote Laboratory Platform

The detailed systematic implementation process of the novel remote laboratory platform is illustrated in Fig. 7. It includes three steps: setup, execution, and localization.

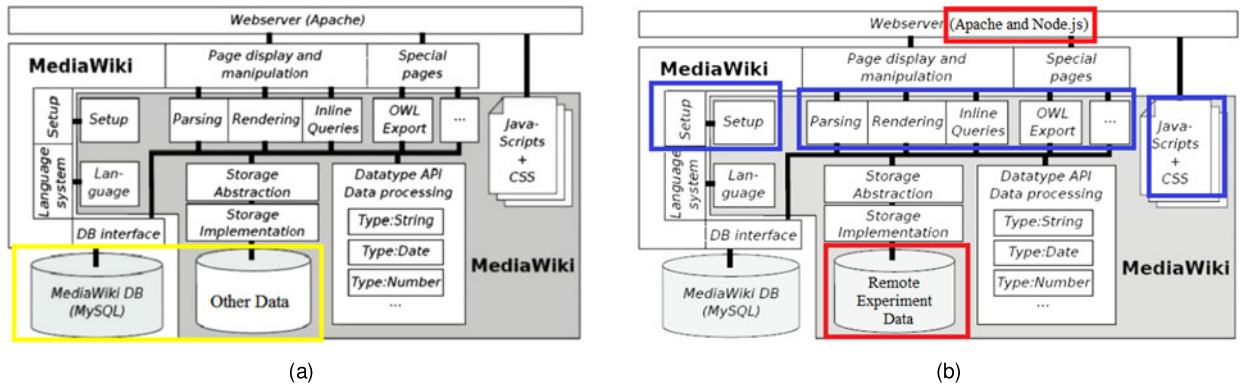


Fig. 6. (a) The system architecture of MediaWiki [34]. (b) The system architecture of novel wiki-based remote laboratory platform.

- 1) *Setup*: To setup the system, the features of MediaWiki need to be registered and configured. Before execution, the novel platform needs to prepare the classes for loading all necessary resources like PHP, JavaScript, and CSS. The novel platform is also directly built on top of MySQL database to store basic experiment data and system information. Some basic parameters of the unified framework for remote laboratory also need to be configured in this process. For example, IP configuration of experiment workstation and web camera, some system parameters of Apache web engine and Node.js web engine configuration, etc.
- 2) *Execution*: On the processing of execution, wiki markup typically contains code that defines and implements custom XML tags, parser functions, and variables. The system will seamlessly integrate MediaWiki with its backing database. It also needs to check contents (such as, remote experiments, learning materials, etc.) for integrity features, add functions for contents management. The scheduler and conflict management module is also executed and to manage the remote experiments at this stage. With MediaWiki's user permission system,

the security system for the remote experiment will be greatly improved.

- 3) *Localization*: MediaWiki has a localization engine to support developing localized systems which are adapted to various languages and regions without engineering changes. As a remote experiment is developed for different societies and countries, the internationalization and localization mechanism are meant to adapting computer software for different languages, regional differences and technical requirements of a target region.

4.2 Created Two Remote Experiments

To illustrate the effectiveness of this platform, two new remote experiments (i.e., remote SVP experiment and remote PID motor speed control experiment) were designed and implemented based on the new platform as shown in Figs. 8 and 9. These two mechanical engineering experiments, SVP experiment and PID motor speed control experiment, have been incorporated as part of the remote laboratory series used in the Intelligent Structural Systems course and the Vibration and Control Lab course at the University of Houston. For the two experiments integration, the detailed process is given below.

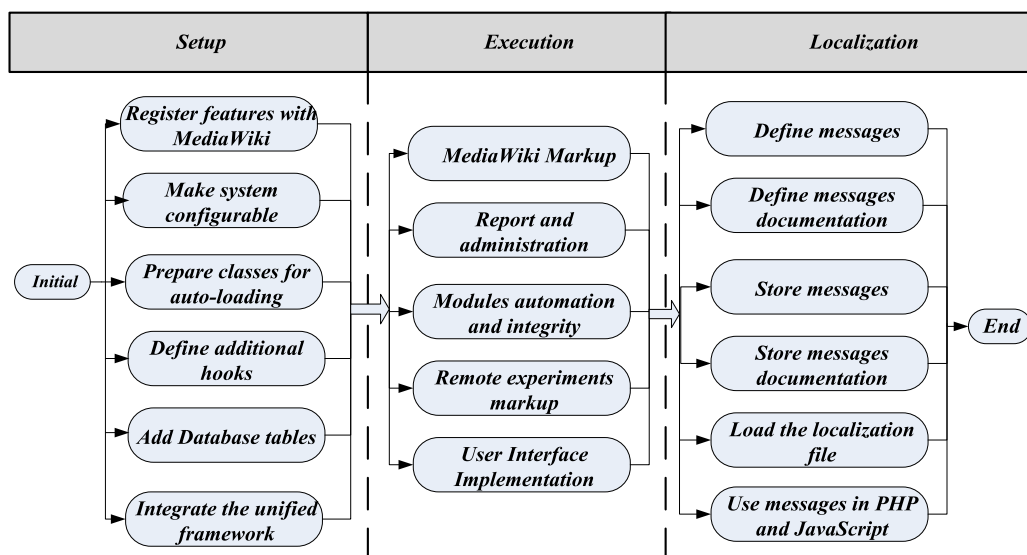


Fig. 7. The implementation process of wiki-based remote laboratory platform.

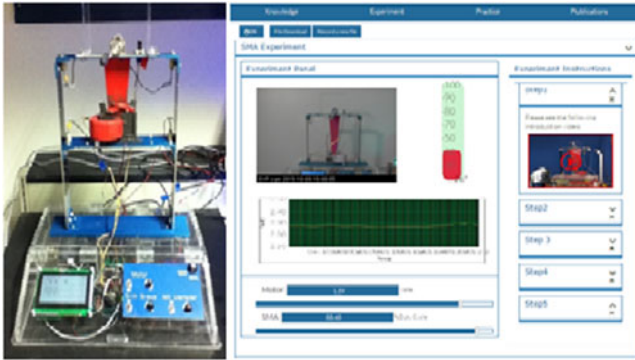


Fig. 8. The SVP hardware and remote SVP experiment user interface.

4.2.1 Experiment Hardware Setup

Remote SVP Experiment. The SVP device, as shown in Fig. 8, is assembled by using fabricated and purchased components. The SVP has a two-story flexible steel frame fixed on top of a plexi-glass box. In the plexi-glass box, there are electric circuit boards made to control the experiment. It was designed and built by students in the Smart Materials and Structures Laboratory at the University of Houston. Other than the flexible steel frame, the SVP has a motor, SMA (Shape Memory Alloy) wires and a magnetized iron clamped on a container of Magneto-Rheological (MR) fluid. The motor with an unbalancing weight is mounted on the top of the frame and connected to the driver from the box on the bottom. When the user controls the current going through the electrical circuit, the speed of the motor can be adjusted. The rotation of the motor leads the flexible frame to vibrate. Two SMA wires are hung across the frame. When the current goes through the wires, the temperature will increase. At a certain point of rising temperature, the SMA wires will shrink in length to reduce the vibration of the frame; this is called a SMA brace. A red steel tongue is placed downwards into the container of MR fluid. The magnetic iron clamped on the container can generate magnetic field when it is turned on. Presence of the magnetic field increases the viscosity of MR fluid because MR fluid changes from fluid state to semi-fluid state under the magnetic field; this is called MR damper.

As it is a remote experiment, users can control the experiment remotely. To let users view the real-time response of experiment, a web camera was connected in the remote laboratory environment. The camera for the SVP was placed on a camera tripod in front of the experiment. A workstation was used to control the experiment, including the heat generation to the SMAs and the strength of the magnetic field. NI LabVIEW is installed on the workstation. Three DAQ 6008 USBs were connected to the workstation, and their voltage outputs and voltage inputs were controlled and sensed by custom LabVIEW program running on the workstation. The workstation is also connected to the web server via a network. All data generated by LabVIEW is sent to the server and control commands are also sent from the server to the workstation via the Internet.

Remote PID Motor Speed Control Experiment. A remote PID motor speed controller experiment is built to demonstrate the characteristics of proportional, proportional-integral, proportional-derivative and proportional-integral-derivative controllers and visualize the process of remote tuning. As shown in Fig. 9, it can help the study of the principle of dynamic

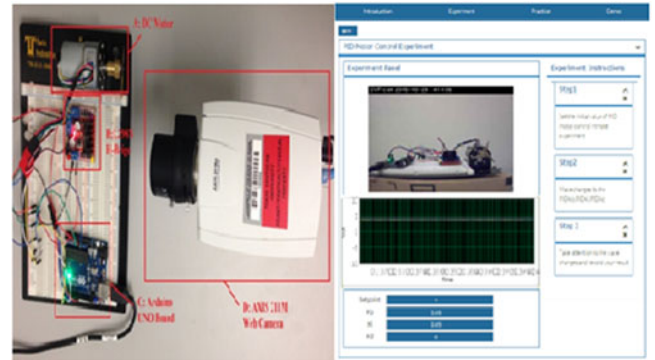


Fig. 9. The PID motor control experiment hardware and remote PID motor control experiment user interface.

systems analysis as well as how to achieve the system optimum behaviors depending on the applications. The controller is designed to control the angular velocity of a DC motor to follow various input signals (i.e., sinusoidal, triangular or square waves) at frequencies of 0.1 Hz to 1 Hz. Both the input and output angular velocity can be adjusted and displayed in real time, while the rotation of motor is able to observe through a webcam in the remote laboratory. The recorded data include input angular velocity, measured output angular velocity and time in seconds. The remote PID motor speed control hardware includes:

- DC motor (Metal Gearmotor 37Dx52L mm with 64 CPR Encoder)
- L298N H-Bridge Motor Controller
- Arduino UNO development board
- AXIS 2111M Web Camera
- PC workstation

Arduino UNO development board is a hardware device utilized to measure the digital signal from L298N H-Bridge Motor Controller as the rotation speed of DC motor and generate digital speed output as control signal to DC Motor. Arduino UNO development board and 12 V DC power supply provide the electronic power to drive the DC motor rotating.

4.2.2 Experiment Software Integration

The software implementation of two remote experiments includes three tasks including the UI integration, platform layer integration and experiment control application implementation.

User Interface Implementation. As the novel wiki-based remote laboratory platform provides the functions to support co-creation of experiment-based learning materials, users can work together to design and implement a new remote experiment UI based on their own requirements. In Fig. 10, two different user interfaces are compared. The Fig. 10a is the old SVP experiment UI based on the unified framework and the Fig. 10b is the new SVP experiment UI based on the novel Wiki-based remote laboratory platform. The prior SVP experiment used a traditional web page that was designed only by the instructor [33]; on the other hand, the new SVP experiment is a co-design outcome from teaching assistants and instructor working together. As shown in Fig. 10b, the UI of novel Wiki-based remote laboratory platform includes five parts:

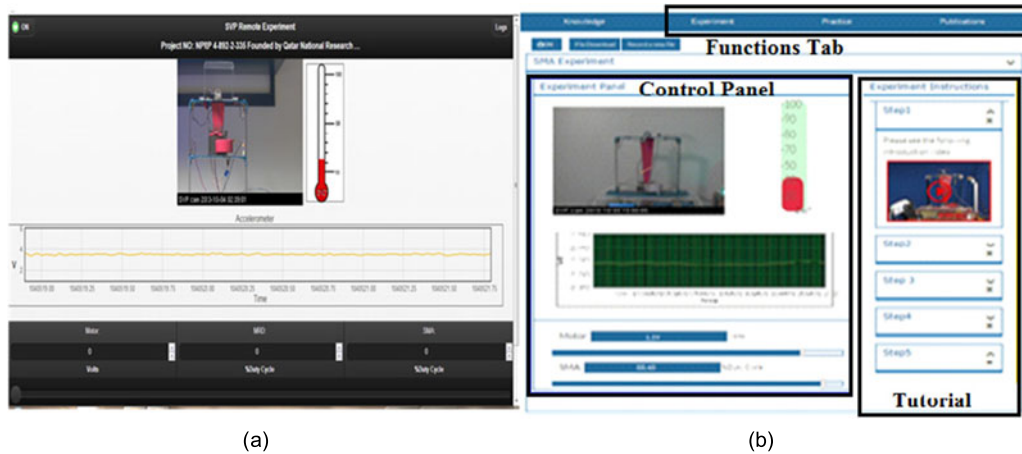


Fig. 10. (a) User interface of the old remote SVP experiment. (b) User interface of the new remote SVP experiment.

- Real-time experiment video (in Control Panel),
- Real-time experiment data display component (in Control Panel),
- Real-time experiment control component (in Control Panel)
- The experiment tutorial (in Tutorial)
- The practices questions, reference contents, and quiz (in Functions Tab).

From the technology point of view, the prior SVP experiment, as shown in Fig. 10a, used Web 2.0 Technology which includes HTML, CSS and JQuery/JQuery-Mobile JavaScript libraries. With the server-based Mashup technology, the data was analyzed and reformatted on the remote server, and then the data was transmitted to the user's browsers. However, for the new SVP experiment based on the novel wiki-based remote laboratory platform, as shown in Fig. 10b, the simple script language (the MediaWiki semantic language) is used to implement the user interface. As the UI design and implementation does not require strong programming skills to be modified, any users can create their own remote experiment based learning materials.

Platform Layer Integration. The platform layer application is directly built on the top of a novel assembled server engine scheme. It includes two server engines working together, Apache HTTP server engine and Node.js server engine. Based on the server-based mashup technology used in the framework, the Apache HTTP server engine is used to integrate the user interface widgets with web content and the real-time experiment video. Meanwhile, the Node.js server engine handles the experiment data in real-time transmission. The experiment scheduler system and user management system also are integrated into the wiki-based novel platform server-side. For the data management, MySQL is used for database management system.

Integrate the LtoN Module to the Novel Platform. A novel real time experiment data transmission protocol, named LtoN (LabVIEW to Node.js), was designed and developed based on Socket.IO and JSON. With the new real time transmission protocol, students can conduct the experiment, save the experiment data, and download the experiment data file. More details of this new data transmission protocol are illustrated in the following

- The new protocol includes two parts, client part running in browsers and server part running in web

server. It was developed using JavaScript language and enhanced by the web socket.

- In this new protocol, we defined our own special communication instruction set to implement real time experiment control commands and experiment data transmission.
- In the new protocol, some brief instructions to control experiment progress are designed to improve the data transmission performance.

Based on the above novel wiki-based remote laboratory platform, two remote experiments are able to provide students support for learning key concepts in mechanical engineering. Students who were enrolled in these two courses were assigned homework in which they operated an experiment remotely through the new platform.

5 FUTURE WORKS

Although the novel Wiki-based remote laboratory platform delivers new functions to support student-centered collaborative learning which cannot be supplied by the traditional remote laboratory platform, there are still further development required to improve the novel platform stability and usability. More specifically, issues that need improvement are as follows:

- 1) More experiments for different disciplines need to be designed. With more and more new requirements from users, more and more new remote experiments need to be designed and implemented based on this novel platform via student-centered co-works in future.
- 2) New solutions and functions need to be explored and implemented. Currently, the experiments is controlled mainly via LtoN protocol based on the PC workstation in this novel platform. In the future, new functions will be integrated to support new hardware solutions to allow remote experiments based on Arduino Yun, Raspberry PI, Intel Galileo, etc., instead of PC workstation.
- 3) Cloud Computing technology should be used. To improve the novel wiki-based remote laboratory platform usability and to provide the remote laboratory services to more users, the Cloud Computing

technology will be used to this novel platform deployment in future.

The implemented two remote experiments have been used in the teaching. Based on a simple survey results, most of students found that these experiments can help them understand the concepts they learned during lecture. However, how to design survey questionnaires to evaluate this new collaborative learning environment with remote laboratory is still a research question yet to be answered.

The novel Wiki-based remote laboratory platform is still version 1.0. So far, only a few pilot tests are conducted. Based on user feedback, several bugs in the software package have been fixed. More comprehensive testing will be done at other universities.

6 CONCLUSION

In this paper, an innovative approach has been proposed for remote laboratory platform development based on a combination of advantages of Wiki technology and a unified framework. With this novel architecture, a more powerful online learning system supported by remote experiments was delivered. It offers a more flexible way to support students' collaborative learning. Compared with traditional remote laboratory exercises, the new platform can also provide more innovative user experience and give students more flexible selection to learn engineering knowledge without the limitation of time and space.

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