

The Establishment of an Interactive E-learning System for Engineering Fluid Flow and Heat Transfer

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Abstract - When it comes to educating and training engineers, the main focus should be on developing their abilities in modeling and analyzing the phenomena for the physical problems. Unfortunately, so far most teaching approaches still emphasize on deriving equations in the classroom. Students' learning motivation and curiosity could be seriously defeated due to the sophisticated and hard deriving progress in order to obtain the solution. In view of this, the present study aims at the development of a web-based learning system in thermal-hydraulics. This system integrates the mature CFD technology to replace the traditional means of derivative of equations. The main structure of this system includes the graphic post-processor, learning materials database, CFD workstation, etc. The demonstration shows that the engineering students do not have to implement the tedious derivative of the complicated equations but solidly understand and efficiently acquire knowledge the course of fluid dynamics and heat transfer through the discussion of physical phenomena by varying parameters by using this web-based learning system.

Key Words- CFD, Engineering education, Fluid flow, Heat transfer, Interactive e-learning

INTRODUCTION

Fluid dynamics and heat transfer, which are usually termed as thermal-hydraulics, are the target courses to be discussed in the present study. In seeking the solution of a flow field or temperature distribution for a specific thermal-hydraulic problem, students can approach the problem in two ways: (1) by deriving mathematical equations from the very basic control volume or (2) by simplifying the governing partial differential equation set. The initial and boundary conditions should also be appropriately specified.

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In order to solve these equations, the barriers that students often encounter are: how to adequately linearize the nonlinear terms and how to efficiently solve the problem using the techniques they learned from engineering mathematics. More than often, an analytic solution cannot be obtained and the situation is even worsened by more complicated boundary and initial conditions. Practically, the goal of engineering training should be focused on the comprehension of the understanding and analysis in physical phenomena and encouraging the creativity in the problem modeling rather than on mathematical processes.

Above reasons usually cause that many students have little interest in learning relational engineering courses. As mentioned in [1, 2], once the phenomena of the problems can be expressed clearly, colorfully and interestingly via graphic visualization, learners' curiosity and motivation in learning and analyzing physical phenomena will be greatly raised. The graphic of the simulation result can be made by post-processor of commercial CFD software. However, seems like the existing CFD software are all stand-alone version, which limited users to execute learning in user's personal computer. Since user's hardware cannot always conform to the requirement of the updated technology, it is a good choice to construct an online e-learning system. A very important advantage of the web-based learning system is that users can connect to the system anytime and anywhere. Users would also be able to conveniently enjoy the information sharing, interactive user interface and so on [3].

We herein try to develop a web-based thermal-hydraulics e-learning system. This proposed system consists of four key components: Interactive user interface (IUI), web and file servers, CFD workstation and controller (CFDW), and teaching materials database. The post-processor plays an important role in IUI, because the post-processor transfers the computational results into the graphic presentation. It offers graphic presentation for users to observe physical phenomena.

BACKGROUND

In recent years, a great deal of effort has focused on the integration of new technologies such as multimedia video

[4], audio, animation, and computers, with associated software, to achieve the improvement of traditional education. The internet technologies have been also popularly applied to web-based learning. Ngo et al. [5] developed an On-line heat transfer and fluid mechanics virtual laboratory utilizing graphic, text, and multimedia. This study focused on teaching experiment related experience rather than discussion of experiment survey theory.

In improvement of engineer education, some authors use CFD (Computational Fluid Dynamics) program to run the case and observe the physical phenomena on single-plane software rather than via internet. Frederick et al. [6-7] used the commercial software, FlowLab, to create a CFD education interface for engineering course and laboratories, had been proven that is an effective and efficient tool to help students learning. Li et al. [8] used the web-base to develop an on-line mass transfer course system. Although his topic with the associate approach is different from ours, they also indicated that learning via internet will be the trend in the future.

The concept of thermal-hydraulics e-learning system was initiated by Hung et al. [9, 10]. They merged existing computational fluid dynamics capability into the e-learning concept to improve traditional engineer education in fluid flow and heat transfer. In the paper, they referred to that HTML (Hyper text markup language) and ASP (Active server pages). In which it provides an interactive user interface as the core of the system and system structure has been preliminarily planned. The prototype of a post-processor program was also established. But the ability of post-processor in drawing for flow field, stream lines, and isothermal contours has to be further enhanced.

Liu et al. [11] quoted the concept of Hung et al. to implement and strengthen the architecture of this thermal-hydraulics e-learning system. In order to establish a cross-platform for e-learning, they used an HTML embedded scripting language, PHP (Hypertext Preprocessor), and integrated with MySQL database management system to manage all teaching materials. Therefore the current stage of effort has primarily focused on the implementation of the system setup.

SYSTEM ARCHITECTURE AND IMPLEMENT

In the current study, we have selected the representative physical problems from the text book of undergraduate fluid flow [12] and heat transfer [13]. The default step of this system is to define the common initial condition and boundary condition for the selected physical problems. These representative problems include no-slip flow on a plate, channel flows, fully developed flow, heat conduction, forced and free convections, and so on.

The commercial CFD software, CFD2000 and Fluent, have been integrated to be the CFD solver workstation. In order to satisfy the corresponding limits with CFD2000 solver, some

teaching martial issues, which case had created by CFD2000, such as phase change and thermal radiation will not be considered. These representative problems had been already established in the system and used this CFD software to simulate and store the results in the database. Users can then alter the physical conditions from the representative problems in the text boxes of web pages. After simulation is finished, the result of simulation will then be stored in the database and displayed on the teaching web page. It is convenient for learners to use this e-learning system anywhere and anytime.

The abundant teaching materials about thermal-hydraulics are shown in the web pages. Learners just read and fined out some topic they are interested in through web browser such as IE or Firefox. At the same time, the interactive user interfaces allow they to enter or change physical conditions and parameters as they wish. System will then check to see whether the condition exists in the teaching materials database. If it does, the result will be displayed in web-base post-processor. Otherwise, system will store those values of physical conditions in the teaching materials database, and wait for implementing the calculation. When the computation for the case with the values input by the learners is completed, the result will be shown in Post-Page for the learners. The calculation results can be review by users no matter either where or when. The flowchart of system is shown as Fig. 1.

The system consists of four key components: Interactive user interface (IUI), web and file servers, CFD workstation and controller (CFDW), and teaching materials database as shown in Fig. 2. These components will be discussed in detail in the following sections.

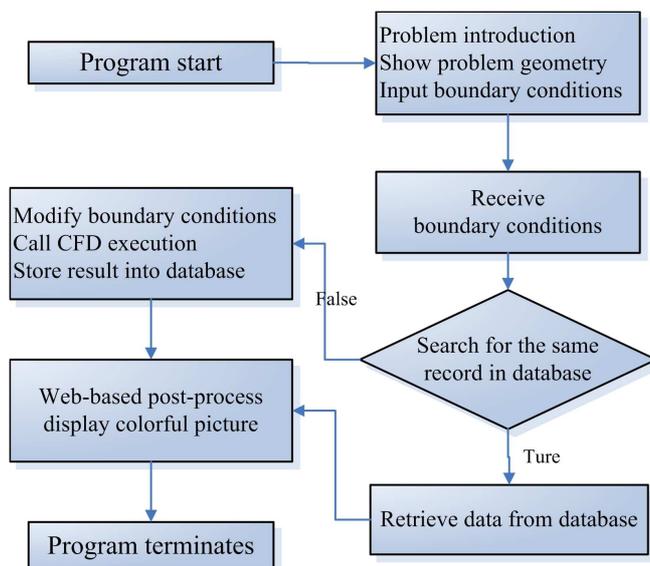


FIGURE 1
THERMAL-HYDRAULICS E-LEARNING SYSTEM FLOWCHART

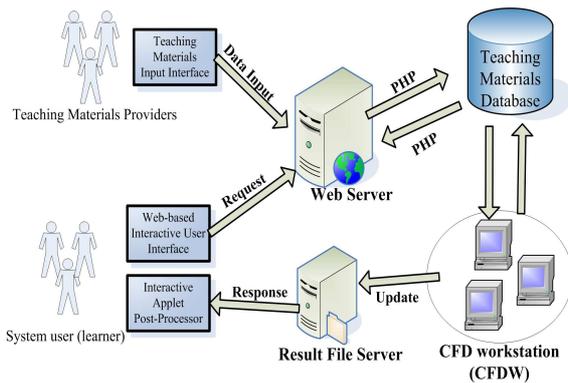


FIGURE 2

THERMAL-HYDRAULICS E-LEARNING SYSTEM ARCHITECTURE

CFD WORKSTATION AND CONTROLLER

CFD workstation is built to calculate the user-selected problem in this system. The commercial CFD package CFD2000 is currently employed to be the core of the CFDW. Several studies have shown that this commercial code is efficient and accurate in academic research and other applications [14-18]. We're confident that CFD2000 will be able to provide the underlying calculation for our purpose.

In addition to the CFDW, CFD Workstation Controller (CFDWC) also plays an important role. The major function of CFDWC is to create the connection between CDFW and Database. In order to provide an interface between database and CFDW, the Application Program Interface (API) is a necessary component. My-SQL supports several classes of APIs for Microsoft Visual Basic programs.

The most striking characteristic of CFDWC is that system administrators can start the CFDW, connect to database, and edit the data stored in the database through CFDWC interface. CFDWC would check if the requested problem had been calculated and stored in the database. If CFDWC could not find the results of the requested problem, CFDW will receive problem file from database by FTP (File Transfer Protocol) and call CFDW to implement the calculation for the problem. At the same time, CFDWC also receives the result file path form the database. After the CFDW completes the calculation, CFDWC will upload the result file to the database server by FTP. The Figure 3 shows the operation chart of database, FTP server, and CFDW.

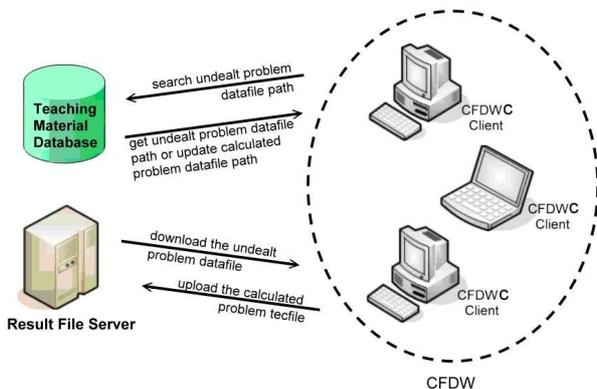


FIGURE 3

OPERATION CHART FOR CFDW & CFDWC

According to this CFDW-CFDWC architecture, the CFD solver is allowed to be change. In order to overcome limits of each different CFD solver, CFDWC is easy to modify to support different type CFD solver such as Fluent or other commercial CFD solver. It is our ultimate goal to integer more and more relational engineering simulation software in the future.

INTERACTIVE USER INTERFACE

There are two sub-components in the IUI. One is the interactive web pages; the other is the web-based post-processor. The basic structure of IUI is very similar to any common web sites, in which HTML comprises the main static structure of IUI, while PHP and JavaScript provide dynamic contents. When a new representative physical problem is added to the system, it must be manually built to be a new teaching web page. If more and more representative problems are created, the system might be filled with repetitious teaching pages and will be eventually difficult to maintain. Therefore, all the teaching contents are arranged to store in the database in order to overcome the barrier like that described above. As long as any user enters the web-site, the affiliated data of the physical problem will be transmitted to IUI by PHP program automatically. In addition, the page frame will be built in just once rather than be created every time.

The web-based post-processor displays the computational result in graphics which shows graphic presentation of computational results. Users can observe physical phenomena via the web-base post-processor. The drawing algorithms of web-based post-processor were developed by Hung [9]. In the present study, the algorithms have been implemented by using Java Applet. Real-time graphical presentation and interactive interface are essential for web-based post-processor. Many literatures have shown that JAVA applet is popular in many related e-learning system in engineering education [19-21]. The Virginia Polytechnic Institute [22] established an engineering course teaching system which was called EngApplets. In which, there are some interactive applets which have been employed to demonstrate the topics such as Fluid Dynamics, Statics, and Dynamics. Page et al. [23] used applet to implement discrete event simulation in their system. They interact with users in the internet by the use of applet interface. According to above studies, it is believed that applet is an appropriate means to implement the interactive interface in web browser.

TEACHING MATERIALS DATABASE

The teaching materials consists two parts: the teaching materials information and the result-file information. The teaching materials information includes the problem illustrations, problem statements, problem indexes, physics variable names, and physics variable values. The result-file information includes boundary conditions; source data file paths, result file paths and CFDW running flags. Both of

them are store at the teaching materials database. MySQL is used as underlying database management system.

Without using of the database, each new problem created by user must be computed every time. Complex problems will take a long time to compute and make it impossible to display the results in real-time. With database, the capability of display in real-time will increase dramatically. For example, as soon as user enters the teaching page, the teaching materials will be shown on the teaching page and users are requested for altering the parameters. If the parameters are stored in the database, the result will be returned immediately. It is also a convenient way to use database to manage numerous teaching materials for the system administrators because they can delete, edit, and add representative physical problems through browser easily. Since not every system administrator is familiar with the technologies such as HTML and PHP, we must build an interface for them to manage teaching materials.

The selection of teaching materials is the important issues. Energy topic is very popular issue around the world in recent days. We try to design some educational teaching material for this topic. The figure 4 was shown as framework of the energy teaching materials. We hope that these teaching materials can help users to acquire more knowledge by our system.

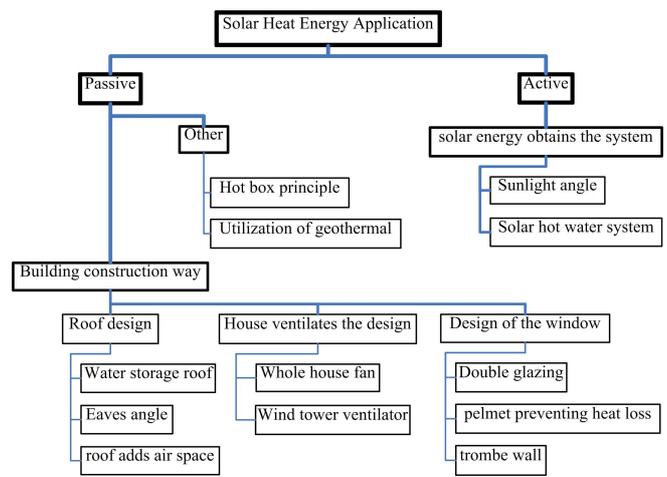


FIGURE 4

THE SCHEMA OF TEACHING MATERIALS FOR ENERGY TOPIC

DEMONSTRATION OF THE SYSTEM

Users can use the web browser to login our system. There are two links, Fluid Dynamic problems link and Heat Transfer problems link, at the northwest corner of initial page. User has to choose the one among of this two links. As user clicks the link, user can select any type of existing problems through the selection box which are consist of all the available representative problems. When the user clicks on the “Done” button, the teaching page link will show the teaching problems with their associate graphic under the selection box.

As an example, if we click the “Heat transfer problems” link, and then select the “classics problems” case in the selection box, the “chip cooling” and other associated problems links will appear on the left frame. When we click the link, the representative case will be shown on the right frame which includes the teaching material. Figure 5 shows the initial screen for a representative problem of the teaching system.

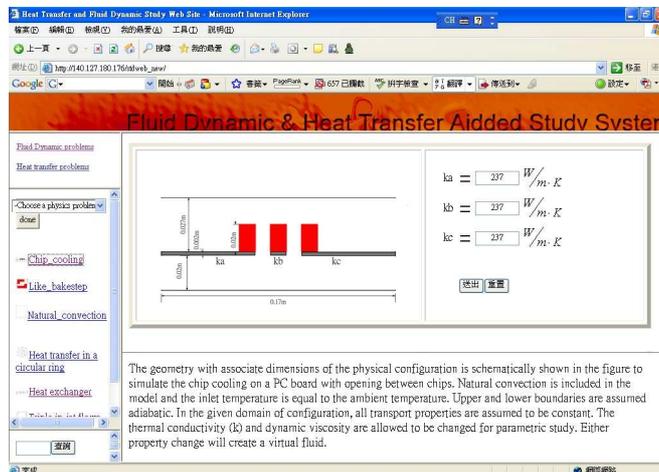


FIGURE 5

THE TEACHING MATERIAL PAGE

There are three parts in the teaching materials page as shown in Fig. 5. The first part is the graphic associated with the underlying problem. It includes names of the changeable parameters and the basic definitions for the parameters of the selected problem. The second part includes the descriptions for the selected problem along with related information to help the users better understanding the selected problem. The third part is the interface that offers users to alter the value of parameters. When user clicks the “finish” button, the updated parameter values will be transmitted to the underlying database.

Following above-mentioned example as shown in Fig. 5, we can see that “Ka”, “Kb”, and “Kc” as given on the right side of the window are initial parameters of the selected representative case. Let’s first not change the initial parameters, and directly click the “finish” button. The parameter values will be transmitted to the database. The result of the representative problem would be shown in the post-processor page, in which the user can observe physical phenomena distinctly as shown in Fig. 6. Basic explanation for its phenomena is provided on the page. In the figure 6, some optional demonstrations of post-processor output, by changing the state of the check-button, for the herein representative case are also shown. After users change the check-button state, the updated graphic will be automatically created and shown in the post-processor page later.

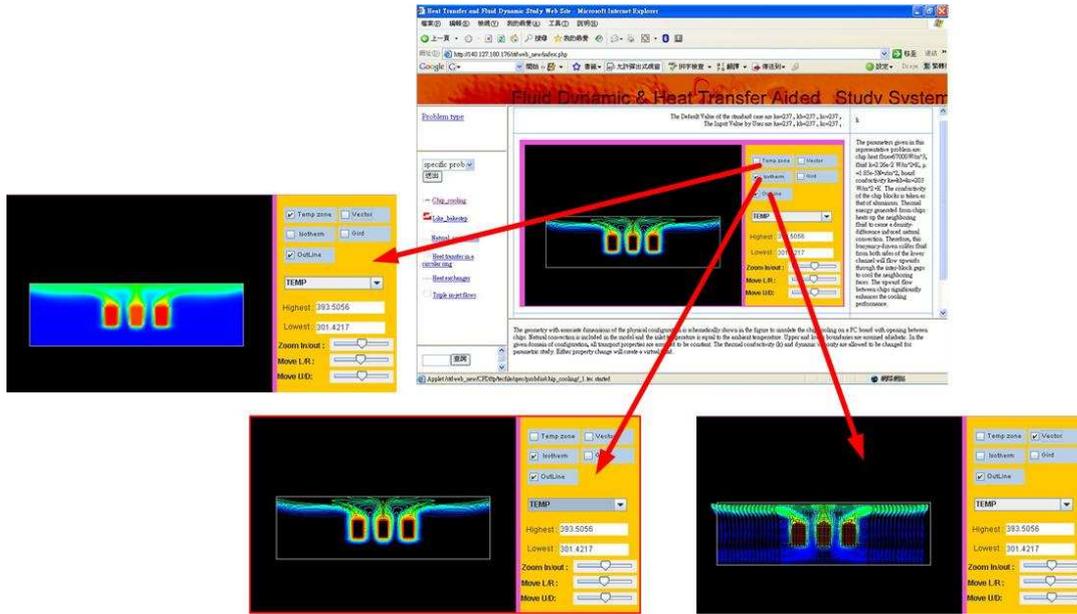


FIGURE 6
THE POST-PROCESS PAGE AND DIFFERENT DISPLAY TYPES

The description of new results is not able to be shown on the web page at this moment of development. If the altered parameter values of the updated problem are not stored in the database before, the teaching problem will pass the parameter values to the database and wait for the calculation by CFDW. More complicate the problem is, the longer it will take CFDW to calculation. Therefore, teaching system will estimate and inform the user as to how long it will take to complete the calculation, and give the user a calculation ID. When the calculation is finished, the user can use the calculation ID to get the result and observe physics phenomena on the post-processor page.

Now, let's create a new case by changing the representative case's parameters, k_a form the default value 237 to 10, and k_c form the default value 237 to 10, and k_b form the default value 237 to 500. Since this new case does not exist in the database, an ID page will be automatically generated by the system and be shown to the user.

After the calculation is done, the result file with the altered parameters will be transmitted to the post-processor page as shown in Fig. 6. The user can learn the modified phenomena and acquire correlation knowledge by this system rather than by solving the governing equations. Figures 7 and 8 further indicate the results of post-processor pages for the changes of " $K_a = 50 K_c = 250, K_b = 500$ " and " $K_a = K_b = K_c = 50$ " from representative case, respectively.

The types and the quantity of teaching problems, which the teaching system offers, have been basically established and will be give more and more for undergraduate engineering students to learn basic concept of fluid flow and heat transfer courses.

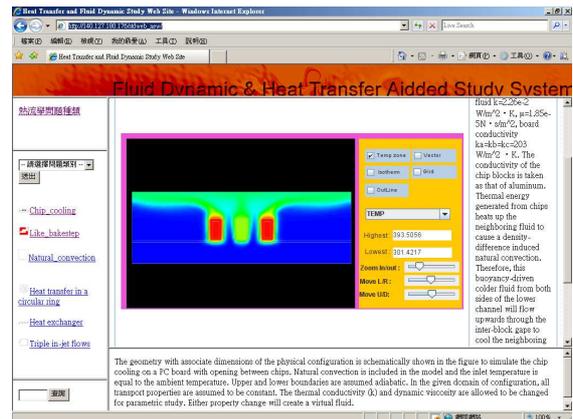


FIGURE 7
NEW PARAMETER FOR $K_A = K_C = 10, K_B = 500$

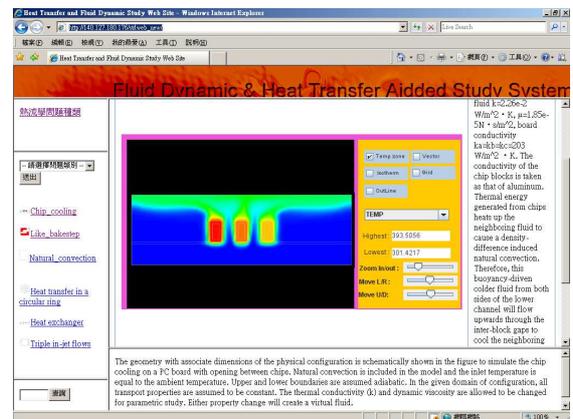


FIGURE 8
NEW PARAMETER FOR $K_A = 50 K_C = 250, K_B = 500$

CONCLUSION

In the present study, a real-time and interactive learning system has been established. Users are allowed that accesses this assisted internet instruction system through web browser no matter where and when. This innovative system provides the engineering students the facility to model problems rapidly and efficiently understanding the associated thermal-hydraulic phenomena without spending lots of time in the derivatives of the governing equations. The main structure of the presently established e-learning system includes GUI, database, CFDW, CFDWC, user-friendly Post-Processor, and learning topics of fluid flow and heat transfer, etc. A large number of teaching materials, which include teaching problems, data files of problems, and calculated results, was stored in database. CFDWC provide not only correctly operation between database and CFD solver but also efficiently handle asynchronous teaching problems submitted from users. Web-based post-processor can successfully draw the colorful simulation graphs of problem. We are also confident that the graphical representation can help users distinctly comprehend different phenomena with dissimilar parameters. The methodological evaluation of this system is the most important work in the future.

ACKNOWLEDGMENT

The authors would like to thank National Science Council, Taiwan, R.O.C, and renewable energy project from Ministry of Education, Taiwan, R.O.C for founding this study. The grant numbers are 95-2516-S-214-001 and 09681201-13-01.

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