

Development and Assessment of WSISLE-CNC for Engineering Education

Wen-Hsiung Wu, Wei-Fan Chen, Tsung-Li Wang, Lung-Ching Fang and Chao-Wei Lu

Abstract—This study developed a web service-based interactive and simulated learning environment for CNC (WSISLE-CNC), based on the simulation design and Web services technology, to assist the teaching and learning for engineering education. The WSISLE-CNC system provides the functions of single-line, multi-line command simulations, and error handling mechanisms. Here we focus on the development of single-line and multi-line command simulations. Then, a questionnaire survey was conducted. The results showed WSISLE-CNC system was strongly supported by both teachers and students from vocational high school.

Index Terms—computer numerical control; Web service; simulation design; e-learning.

I. INTRODUCTION

The training program of Computer Numerical Control (CNC) is important in the engineering education. Learning parametric programming and machining operations of CNC, such as repeat drilling or tapping operations on a workpiece, is crucial for the students. Hence CNC learning becomes the foundation of computer aided design (CAD) and computer aided manufacturing (CAM) course education. However, due to the high costly to install CNC machine tools, lack of enough hands-on experiences for learners, and damage to CNC tools causing from misuse, we found good learning performance may not be achieved.

Simulation design is one of the most useful approaches to solve the above problem. Researchers believe that supporting simulation tools can improve student learning. Simulation makes learners take active part in learning [1]. Simulation is considered to be an effective and efficient teaching method, and to be suitable in the complex and dynamic operations for saving learning time [2]. When the Internet-based

development context is gradually mature, we found CNC studies related to the instructional simulation systems have made some valuable progress. For example, Cheng [3] applied the common object request broker architecture (CORBA) to design a distance CNC program instructional simulation system. Ong and Mannan [4] used Java and VRML to construct a virtual CNC environment providing fill-in-the-blank, insert-the-word, and viewing functions. Although past studies have constructed a valuable web-based learning environment, however, few emerging technologies and applications, such as Web service, were adopted to develop an advanced learning environment. Vossen and Westerkamp [5] mentioned e-learning can be viewed as Web service. Hence Web service technology is proper to develop CNC simulated learning environment.

The purpose of this study is to develop a Web service-based interactive and simulated learning environment for CNC (WSISLE-CNC) based on simulation design and Web Service technology. Then, this study conducts a questionnaire survey with teachers and students of vocational high school in Taiwan to assess WSISLE-CNC system for its teaching and learning assistance.

II. THE FOUNDATIONS OF SYSTEM DEVELOPMENT

The foundations integrate experts' knowledge of engineering education with new advanced technology. First, we invited mechanical engineering teachers and experienced experts in vocational training units in the project to contribute their expertise. Hinostroza and Mellar [6] asserted the importance of the teachers involved in the design of teaching software. Teachers can integrate their teaching strategies with the design of teaching software. Kong and Kwok [7] depicted the pedagogical content knowledge from experts and educators are helpful to better accept a learning system for students. As a result, this study organized the CNC concepts in three parts: (1) basic CNC milling machine and lathe operation, (2) CNC milling machine and lathe programming, and (3) CNC milling machine and lathe machining. For the first part, the basic operations mainly consist of how to operate milling machines and lathes, how to use the control panel, control functions, button functions, and how to use the cutting tool installation and setting. For the second part,

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programming is composed of the introduction to the standard syntax and command set of milling machine and lathe numerical control codes. For the third part, we use questions of milling machine and lathe machining from the national technician's test in Taiwan as examples, and provide more detailed explanation of code operation.

Second, we adopted Web service technology to develop the WSISLE-CNC system. Based on service-oriented architecture (SOA), Java programming language was used to develop this system. The Web service architecture can provide advantages to integrate the applications from heterogeneous contexts and to present flexible, reusable, highly-efficient, and dynamic services [8, 9], which enhance its teaching and learning assistance.

III. THE SYSTEM FRAMEWORK OF WSISLE-CNC

The WSISLE-CNC system architecture consists of four parts: (1) User terminal, (2) Application (AP) server, (3) Content server, and (4) Universal Description Discovery and Integration (UDDI) server. User terminal is composed of the computers used by teachers and students, and browsers used for entering the system. The AP server is responsible for handling the CNC code editing. CNC code editing functions include single-line command simulation and multi-line command simulation services. The content server can store kinds of contents into various databases, including a management base, rule base, and user history and records base. The UDDI server provides Web services registration and message transmission through Internet.

Regarding the interaction between various parts of the WSISLE-CNC system, AP server of the CNC code editing features required by the UDDI server to register and publish. After passing authentication and authorization through HTTP and SOAP, user terminal can enter the system AP server and database servers to access teaching and learning services. Web server services are managed by Apache and Tomcat servers. WSISLE-CNC's Web services are supervised by the AP server. Databases on the AP server and content server are linked through ODBC.

IV. THE MAJOR FUNCTIONS OF WSISLE-CNC

This study focuses on the design of CNC code editing functions of single-line and multi-line command simulations (Fig. 1). The following section provides a detailed description of the design of these aspects. In line with the virtual CNC environment proposed by Ong and Mannan [4], CNC code editing function design of this study provides both single-line command simulations and multi-line command simulations. For the single-line command simulations, this system is upgraded by allowing learners to enter numerical values such as coordinates (fill-in-the-blank approach) to a full command

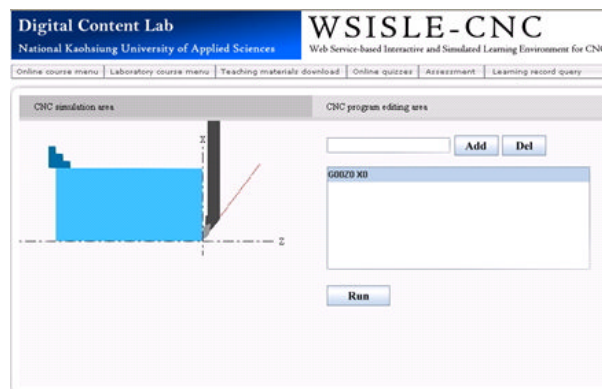
and parameter input approach. The multi-line command simulation design is upgraded by allowing learners to input progressively a series of four steps (four steps' insert-the-word approach) to a flexible multi-line command writing approach with an unrestricted number of lines.

In summary, the functions of WSISLE-CNC provide the CNC commands and parameters without any limit in the number of lines. The following subsections are descriptions the single-line command and multi-line command simulations and its examples.

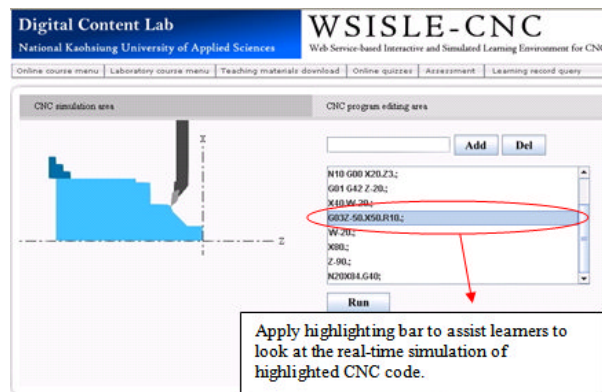
1) Single-line command simulation

This WSISLE-CNC implements single-line program codes and it has to be simulated with a single line, such as G00 (rapid traverse), G01 (linear interpolation), G02 (clockwise circular interpolation) and G03 (counterclockwise circular interpolation) CNC commands. The right half of the interface in Fig. 1(a) is the CNC program editing area; this area contains a "text input field" and "Add" and "Delete" buttons, program code menu, and a "Run" button. The left half of the interface is a simulated cutting tool movement and cutting object simulation area.

For example, Taking the G00 command and simulation process as an example, when a learner inputs "G00Z0X0" in the text input field and clicks on the "Add" button, the command code entered by the learner will appear on the program code menu in the bottom part of the screen. The



(a) Single-line Command Simulation



(b) Multi-cycle Simulation

Figure 1 Snapshots of Basic CNC Code Editing Functions

learner can next press "Run" and the system then converts the code to a cutting tool movement path array for drawing simulation graphics.

2) Multi-line command simulation

Apart from single-line command simulations, the system implements multi-line command simulations, such as combinations of the foregoing G00, G01, G02, and G03 commands, as well as G71 (set metric units), G72 (finished cut along z-axis), and G73 (peck drilling cycle) commands for multi-cycle programming. The right half of the multi-line command simulations interface (Fig. 1(b)) is the CNC program editing area, and the left half of the interface is a simulated cutting tool movement and cutting object simulation area. The highlighting pointer shown in Fig. 1(b) allows learners to perform real-time simulations of highlighted CNC code, helping them to understand the relationships between pieces of CNC code and the resulting simulation graphics.

For instance, regarding the multi-line CNC command writing and simulation process, when a learner inputs a multi-cycle program in the program editing area and presses the "Run" button, the system will identify the movements and parameters in the program code, and converts them to a cutting tool movement path array for drawing simulation graphics. In addition, the cutting tool will first move to the cycle starting point at the beginning of the simulation, and afterwards complete the multi-cycle rough cutting process. Finally, the system will implement fine machining and display the final simulation graphics.

V. THE ASSESSMENT OF WSISLE-CNC

A questionnaire survey was designed to collect data from students and teachers at a vocational high school in southern Taiwan. The students were third-year high school students majoring in machinery and then enrolled CNC machining practice course and laboratory. These teachers all had many teaching experience. In addition, the respondents all had software and network use experience, including word processing and Internet use.

On the manipulation, all participants are brought together into a computer classroom linked to a network. The participants could access CNC code editing functions on a server. Participants performed a self-study session that included operating the WSISLE-CNC system. Then, a questionnaire items modified from the research of Kong and Kwok [7], Davis [10], Venkatesh and Davis [11], and Evans et al. [12], was conducted to conclude the self-study. These questions asked the participants their attitude towards CNC code editing functions, including their interaction and use, usefulness, and intention to use these features.

The results of questionnaire survey are described as follows. Based on 7-point Likert scale (1 for "strongly disagree" and 7 for "strongly agree"), the students' responses about single-line command simulations showed overall mean (standard deviations) of 5.35 (1.19) for usefulness, 5.70 (1.11) for intention to use, and 5.40 (1.12) for interaction and use, while the teachers' responses displayed 6.11 (0.85) for usefulness, 6.67 (0.47) for intention to use, and 5.33 (1.11) for interaction and use. For multi-line command simulations, the

students' responses presented overall mean (standard deviations) of 5.42 (1.15) for usefulness, 5.77 (1.04) for intention to use, and 5.35 (1.15) for interaction and use, while the teachers' responses showed 6.11 (0.85) for usefulness, 6.67 (0.47) for intention to use, and 5.33 (1.11) for interaction and use.

VI. CONCLUSIONS

The contribution of this study is to develop the WSISLE-CNC system to assist teaching and learning for engineering education. The main functions of this system consist of single-line and multi-line command simulations base on the simulation design and Web service technology. Especially, the new emergent technologies can apply to the design of interactive and simulated learning environment. Moreover, the results of questionnaire survey show that WSISLE-CNC is strongly supported by both teachers and students, who expressed that these mechanisms promote CNC course teaching and learning.

Further research can continue to develop the advanced functions of error handling mechanisms, such as pop-up window and sound effects or graphic comparison, to more assist teaching and learning for CNC training. Moreover, researchers can design a broader questionnaire survey with students and teachers at different vocational high schools for further assessment of WSISLE-CNC system.

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REFERENCES

- [1] G. Kearsley and B. Shneiderman, Engagement theory: a framework for technology-based teaching and learning, *Educ Tech* 38 (1998), 20–23.
- [2] A. Parush, H. Hamm, and A. Shtub, Learning histories in simulation-based teaching: the effects on self learning and transfer, *Comp Educ* 39 (2002), 319–332.
- [3] S. I. Cheng, A study of a remote CNC instruction simulation with CORBA technology, The 3rd National Conference on Precision Mechanical Manufacture (2003), 676–682.
- [4] S. K. Ong and M. A. Mannan, Virtual reality simulations and animations in a web-based interactive manufacturing engineering module, *Comp Educ* 43 (2004), 361–382.
- [5] G. Vossen and P. Westerkamp, E-learning as a web service, The 7th International Database Engineering and Applications Symposium, (2003), 242–249.
- [6] J. E. Hinojosa and H. G. Mellar, Pedagogy embedded in educational software design: report of a case study, *Com Educ* 37 (2001), 27–40.
- [7] S. C. Kong and L. F. Kwok, An interactive teaching and learning environment for graph sketching, *Comp Educ* 32 (1999), 1–17.
- [8] J. Rodriguez, L. Anido, and M. J. Fernandez, How can the web services paradigm improve the e-learning? The 3rd International Conference on Advanced Learning Technologies, (2003), 479.
- [9] Z. Xu, Z. Yin, and A. Saddik, A web services oriented framework for dynamic e-learning systems, *IEEE CCGEI* 2003 2 (2003), 943–946.
- [10] F. D. Davis, Perceived usefulness, perceived ease of use, and user acceptance of information technology, *MISQ* 13 (1989), 318–339.
- [11] V. Venkatesh and F. D. Davis, A model of the antecedents of perceived ease of use: development and test, *Deci Sci* 27 (1996), 451–481.
- [12] C. Evans, N. J. Gibbons, K. Shah, and D. K. Griffin, Virtual learning in the biological sciences: pitfalls of simply "putting notes on the web", *Comp Educ* 43 (2004), 49–61.