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Enhancing Mechatronics Learning through Human Computer Interaction Technology*

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The introduction of human computer interaction (HCI) technology has made the teaching curriculum for engineering far more stimulating and approachable. This study proposes the use of a graphical human interface to facilitate learning in an experimental module in mechatronics. Students learn the principles, function, and application of mechatronics via the interface to demonstrate the use of technology in human-computer interaction. This study focused on five main elements: (1) The development and testing of a learning platform for the mechatronics module; (2) learning exercises specifically tailored to laboratory objectives; (3) the convenience and user-friendliness of the proposed system; (4) the technical aspects of the platform in question; (5) the development of approaches to further enhance learning. This paper makes two fundamental contributions to the field of mechatronics education. First, we have developed a system that provides greater flexibility, accessibility, and ease of use for students. Second, we present an approach to curriculum development that is demonstrably faster in its progress from design to process planning.

Keywords: human computer interaction (HCI) technology; mechatronics; monitoring; control system

1. Introduction

In engineering education, lectures are traditionally followed up by laboratory work. Students undertake experiments, which allow them to apply theoretical knowledge to practical problems [1]. Laboratories are viewed as indispensable, particularly for undergraduates who require access to facilities for experimentation [2–3]. The benefits of utilizing information and communication technology in engineering education are multi-fold [4].

Laboratories are an important element of engineering education, in which students apply the theories they have learned during class for the development of practical skills. Laboratories are also important in engineering research to evaluate theories using different systems. In the field of education, laboratories are required to familiarize students with the facilities and equipment used to conduct experiments [5].

Human computer interaction (HCI) is a field of scientific study working within an intuitive framework [6], involving the design and application of interactive systems for human use [7–8]. HCI involves input and output devices and the interaction between them. Interaction between a user and a computer takes place at a user interface comprising both software and hardware [9]. HCI design was created specifically to attune the behavior of a system with the way a user perceives the system's behavioral model. It is assumed that eliminating the difference between the system and the mental framework of users makes the system easier to operate [10]. It has been observed that students habitually opt for graphical human computer interaction over traditional command-line interfaces [11–12]. Thus, graphical human interfaces now play an ever more important role in the classroom, as they offer an approach that is both accessible and visual [13–15] and therefore pleasurable to use.

Using applied engineering techniques in the classroom enriches and enhances the curriculums. Most technological applications use a graphical user interface to establish a user-friendly environment [16]. A basic design goal of the user interface design is to match the behavior of a system to the expectations and requirements of the user. It is assumed that by eliminating discrepancies between the structure of the system and the mental model held by users, the mental effort required to operate the system would be reduced [17].

The field of mechatronics comprises mechanical, electrical, engineering and information system elements, all of which are integrated into the main body of a mechatronics course. This has resulted in an interdisciplinary approach to mechatronics that is both dynamic and versatile. Students in practical lessons are generally supplied a variety of actuators and sensors, as well as data collection and control tools. This equipment facilitates a variety of solutions to a plethora of design problems. Various studies [18] have described laboratory learning modules developed and taught in manufacturing and robotics courses. In short, it is clear that an accessible broad-based program, including the adoption of projects designed by students through

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computer manipulation, stimulates ingenuity, originality and motivation regarding the subject matter [19–20].

Only limited research has been dedicated to HCI technology, automatic control systems, and graphical user interfaces in the context of learning mechatronics. The aim of this study is to illustrate the superior learning support afforded by HCI technology in the education of mechatronics and explore other applications. To this end, we established a laboratory platform for experimental studies. The modules presented are applied systems appropriate for engineering education with practical mechatronics examples provided. This includes an experimental module designed in accordance with the graphical monitoring and control system at the Department of Industrial Education and Technology at National Changhua University of Education. An introduction to automation control is an essential aspect of a course in mechatronics, graphical monitoring and control system fundamentals, due to the opportunity it provides for students to explore mechatronics in ways typically applied in industry. The developed system can be used to organize various data, before integrating it into the experimental mechatronics module by way of student-made projects. It can also edit graphical human computer interaction monitoring and control system software. Finally, it connects the software with the hardware of mechatronics devices resulting in an experimental module based on the graphical monitoring and control system. Experimental instruction material offering practical graphical monitoring and control system experience to team-project students is also presented in this article.

The system integrates mechatronics systems in a learning environment at the technological level. At the learning level, the system builds on modules and functionalities in realistic learning scenarios to introduce the operation of actual mechatronics module and to teach skills associated with programming a graphical monitoring language. At the experimental evaluation level, evaluation is utilized in order to elevate the standards in terms of teaching and learning. Evaluation quality has a marked impact on student willingness to work hard, and encourages teachers to focus on ways of improving individual learning attitudes.

The remainder of this chapter is organized as follows: Section 2 identifies the requirements of human computer interaction system used in mechatronics engineering education. Section 3 outlines the experiments employed in the proposed system. Section 4 details the experimental module of the mechatronics project. Section 5 provides a discussion and our results. Finally, conclusions are presented in Section 6.

2. Human computer interface system

In this section, the human computer interface system requirements for mechatronics engineering education are outlined.

2.1 General description

Graphical monitoring and control devices with the following functions: (1) Mechatronics status monitoring; (2) Device information collection; and (3) In-depth analysis and trouble-shooting.

2.2 System description

The system in our study included the mechatronics module for HCI technology, device interface hardware, inter-communication wiring, a personal computer, software, and ancillary equipment. A personal computer connected to the human computer interface device could access data supplied by the mechatronics module and use it to centralize the data display, as well as to implement other monitoring and control functions.

The most important part of the system is the implementation of a mechatronics experimental module based on the HCI technology found in laboratories. The students engage in active learning by actually performing experiments; this is as important as the passive learning involved in simply attending laboratory lectures.

3. Description of experiment

3.1 System structure

Implementation of the mechatronics module in conjunction with the programming logic controller and HCI (device and software) is the most important aspect of the system. Figure 1 presents this system structure.

3.2 Learning objectives

From a technological standpoint, the system combined the human computer interface device and mechatronics module within a learning environment, while from an educational perspective, the system built on modules within a framework of authentic learning scenarios. While learning the skills required to program software, bona fide functioning systems were produced. Finally, the effectiveness of a variety of learning programs was assessed using an evaluation protocol combining qualitative and quantitative ratings; the goal here was to identify new designs for the field of engineering education.

As shown in Fig. 2, we also employed direct instruction strategy [21], which is indispensable to

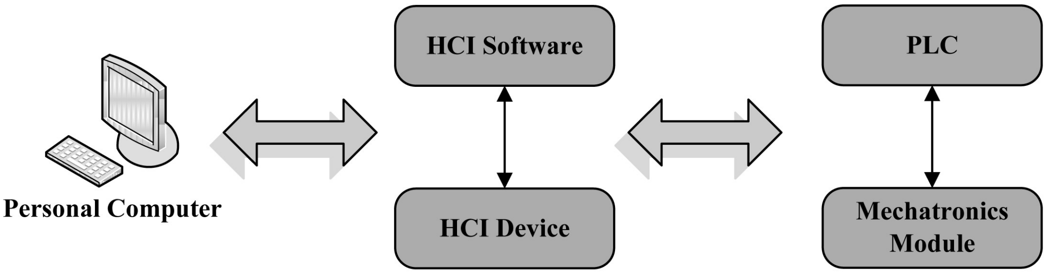

Fig. 1. System structure used for experiments.

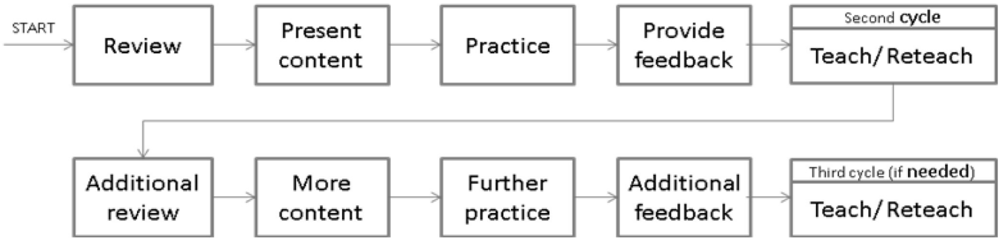

Fig. 2. Direct instruction strategy.

the conveyance of fundamental facts, rules, and sequences essential for all subsequent learning.

Thus, a key objective of our study was the maintenance of the system to enable students to experience the design and implementation of an entire mechatronics manipulation program in a real-life situation. This study focused on the following two areas [22]:

(1) Technological: Exploring the adaptation of concepts and techniques with the aim of introducing them in laboratory settings.
(2) Educational: In order to learn mechatronics manipulation principles students had to become familiar with mechanical and control engineering concepts and skills.

4. Project experiment

4.1 Using the mechatronics module in the laboratory

There are many advantages to the mechatronics experimental module. It is convenient and user-friendly, and easy to adapt or combine with other mechatronics systems. The laboratory can be set up with a purpose-designed interface for experimentation and the relaying of instructions. Students can use software to design their own control programs for the mechatronics module. A mechatronics module for use in laboratory experiments is presented in Fig. 3, while Fig. 4 shows the pneumatic scheme for the mechatronics module. The PLC software programming for the mechatronics module is displayed in Table 1.

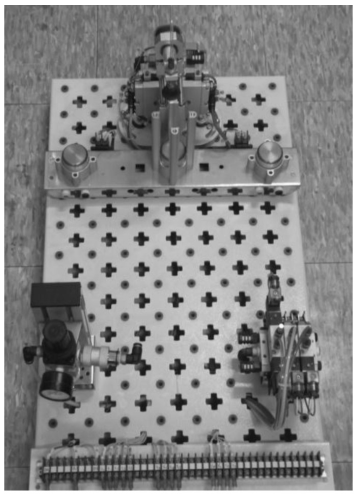

Fig. 3. Mechatronics module.

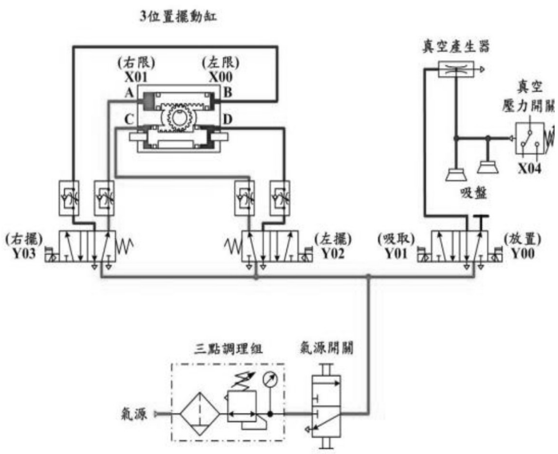

Fig. 4. Pneumatic scheme.

Table 1. PLC software programming for mechatronics module

PLC Contact Point	Function
X00	Left limit switch
X01	Right limit switch
X02	Left-end material sensor
X03	Right-end material sensor
X04	Switch sensor
X10	Start button
X12	Selection button
X13	Emergency button
Y0	Capturer off
Y1	Capturer on
Y2	Left moving motor
Y3	Right moving motor

4.2 System integration test

As shown in the system structure in Fig. 1, the human computer interface device for the mechatronics module was designed to assess the effectiveness of the system we propose. Fig. 5 presents a comprehensive HCI device designed especially for use in mechatronics monitoring and regulatory systems. The device is connected to the host computer through RS422-RS232 twisted pair interfaces, and all indicators show the input (X) or output (Y) of the mechatronics module.

We compared the mechatronics module with a commercial mechatronics system, from an educational usability standpoint. Undergraduate students were introduced to a human computer interface device for the mechatronics module, many of whom had no previous experience with such a system. In comparison with conventional mechatronics systems, this system displayed the following benefits: (1) it was more accessible to the students and easier to use, and (2) the progression from design to process planning was completed more rapidly.

Fig. 5. The comprehensive HCI mechatronics monitoring and control system.

5. Discussion and results

Most studies in this field have reported on the development of modules for the instruction of mechatronic [23–25]; however, few papers have even attempted to integrate mechatronics with HCI technology for academic research.

Kayaoğlu et al. [26] and Aktaş et al. [27] adopted a small sample size to compare two different groups in statistical analysis. Kayaoğlu et al. investigated whether a difference exists between learning vocabulary via animation and via traditional paper-based method. This small scale study was selected as the experimental group (n = 17), and control group (n = 22). Aktaş et al. investigated that teaching of different pattern types by using computer animations and activities. The sample in their study was 28 eighth grade students.

This study employed eight experts in the field to evaluate the laboratory platform and determine the accuracy of the embedded knowledge as well as the effectiveness of the proposed system. The experts were university professors and/or researchers with an average of more than five years of experience in teaching mechatronics.

This study was performed in the Department of Industrial Education and Technology at National Changhua University of Education in Taiwan. Eighteen undergraduate students participated in the course, for which the laboratory element comprised both lectures and experiments managed by one teacher and one graduate assistant. Students were given preparation time prior to the laboratory work and were required to write a report upon completion of the exercises. At the end of the project, students were able to choose whether to take a final exam or be assessed on the basis of project work.

To increase the accuracy of our results, more than one data collection method was employed. We used a questionnaire, interviews, and observation in the assessment of the mechatronics module. Students were requested to answer an anonymous questionnaire according to a Likert scale ranging from 1 = "strongly disagree" to 5 = "strongly agree".

Questionnaire details and results are presented in Table 2. According to the results of the evaluation, both groups rated the proposed system very highly. Further analysis was conducted to determine whether the experts and students differed in their mean ratings related to the effectiveness and usability of the system. Because the sample size was small, we used the nonparametric Mann–Whitney U-tests with the level of significance predicated on $p<0.05$ [28]. The corresponding two-tail critical value was ± 1.96. The mean ratings of the experts regarding the effectiveness and usability of the system did not

Table 2. Mann-Whitney U-test results of Survey

Assessment Items	Groups	n	Mean	SD	U	*p*
Q1. The module was challenging and interesting.	Experts	8	4.25	0.463	–0.456	0.648
	Students	18	4.33	0.594		
Q2. I have learned useful information during the module.	Experts	8	4.25	0.463	–0.069	0.945
	Students	18	4.22	0.548		
Q3. The background information was clearly written	Experts	8	4.25	0.463	–0.069	0.945
	Students	18	4.22	0.548		
Q4. The module materials were helpful.	Experts	8	4.13	0.641	–0.494	0.621
	Students	18	4.00	0.594		
Q5. I will recommend this module to other students.	Experts	8	4.13	0.641	–0.066	0.947
	Students	18	4.11	0.583		
Q6. The materials were in adequate supply.	Experts	8	4.13	0.354	–2.133	0.033*
	Students	18	3.61	0.608		
Q7. There was adequate practice.	Experts	8	4.13	0.354	–2.133	0.033*
	Students	18	3.61	0.608		
Q8. The module resembles real industrial processes.	Experts	8	4.25	0.463	–0.069	0.945
	Students	18	4.22	0.548		
Q9. The module works as intended.	Experts	8	3.88	0.354	–1.271	0.204
	Students	18	3.61	0.608		

*p<0.05.

differ significantly from those of the students, except for Q6 and Q7. The responses to these questions show a general opinion indicating insufficiencies of the materials and practices. In the future, it is recommended that the instructor improve the curricular materials where the budget allows.

6. Conclusions

This study explored the development of the mechatronics experimental module using the human computer interaction technology with monitoring and control system to enhance learning. Both theoretical and practical applications were highlighted by this system and the course covers conventional technology as well as cutting-edge mechatronics design. It is hoped that this system will help to bridge the gap between university education and mechatronics in industry. The flexible nature of the platform presented here can help cultivate in students the ability to respond to the ever-changing world of industry, and is a useful and effective alternative to more traditional approaches. The innovations and learning methods acquired in this study have been inaugurated in the department of industrial education and technology at National Changhua University of Education.

The proposed mechatronics module was compared to a conventional mechatronics system from the perspective of educational applicability. Undergraduate students were introduced to human computer interaction technology for a mechatronics system. Compared to conventional approaches to the instruction of mechatronics, the proposed system displayed the following characteristics: (1) greater accessibility and user friendliness, and (2) faster progress from design to process planning.

Although these results provide insight into the effectiveness of various learning initiatives, a number of limitations must be addressed when interpreting them. First, this study presents our testing of a theoretical model, and should be subjected to further testing with different participants, contexts, and technological architectures. Second, the participants were undergraduate students who were completing the course as part of a degree requirement; therefore, these results are not generalizable to other settings or contexts. Issues related to the motivation of the undergraduates to participate in research may also have influenced the results.

Flexibility in the design of the proposed module allowed us to balance progressive learning methods with contemporary instructional strategies. This study sought to establish the foundations of technology for human computer interaction to enhance the learning of mechatronics and develop an instructional design tailored to the needs of students. It is hoped that this proposed human computer interaction technology can be helpful in mechatronics learning as a useful and reasonable alternative.

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