A CASE STUDY OF MECHATRONICS EDUCATION IN PRODUCT DESIGN COURSE USING A TEACHING TOOL FOR PIC PROCESSOR

Atsushi MITANI
School of Design, Sapporo City University

ABSTRACT
This paper described outline of the mechatronics class in the Product Design Course of the School of Design, Sapporo City University, Japan. The mechatronics is an essential technology for various industrial products. In the curriculum of product design education, there are few classes regarding mechatronics to realize functions embedded in products, whereas many classes regarding design expressions using computer software. To propose an effective design to the mechatronics-embedded products, the mechatronics lectures should be included in the curriculum of product design education. For the mechatronics class I offered, a printed circuit substrate was developed to study electronic devices and a PIC processor for design expressions. The lecture included PIC assembler programs for LED blink control, feedback from sensors and switches, the driving of servomotor, and the sequential feedback. This class was done by an assignment to produce an actual model for an interaction design with human actions using these skills.

Keywords: Mechatronics education, educational tool, PIC processor, interaction design

1 INTRODUCTION

The mechatronics is an essential technology for various industrial products. In the curriculum of the school of product design, there are few classes regarding mechatronics to realize functions embedded in products, whereas many classes regarding design expressions using computer software, for example, animations, movies, computer graphic (CG) images, rendering, computer-aided design (CAD) and 3D modelling tools. These cause that product designers can not propose an effective design to the mechatronics-embedded products, since they do not have knowledge and skills to apply the mechatronics for design expression on actual products.

While the fusion of the product design and mechatronics technology seem to be accomplished in a product, they are based on quite different concept each other. Therefore, various particular design expressions using the mechatronics technology cannot be incorporated in actual products. This means that the existing design techniques are effective for the static modelling, but they do not have been produced to examine dynamic design expressions brought by the mechatronics technology. In order to improve them, product designers need to study the mechatronics technology and its characteristics, and pursue mechatronics-based design expressions.

I offer a mechatronics class to promote better understanding as to basic knowledge and technology of mechatronics for students belonging to the Product Design Course, School of Design, Sapporo City University, Japan, so that they can acquire design expression techniques by the hardware control using the mechatronics technology. As an educational tool in this class, we developed a printed substrate to study an electronic circuit and a PIC processor for design expressions with a practical guide of PIC assembler instruction and sample programs. Using this tool, students can learn the PIC assembler programs for on/off action of LED, blink control of LED by time delay process, LED lighting interlocking with switches, and motion control of servo motor by sensor feedback.

This paper described the abstract of the mechatronics class using the educational tool developed and achievements of the assignment this class entitled "development of an interactive tool with human actions."

There are many educational tools to teach mechatronics. An introduction education through a robot contest named the "Robot Triathlon" is conducted [1]. Using a standard robot kit for this robot contest,

students can study the foundation of autonomous control, C-language programming for a H8 microprocessor, Renesas Electronics Corporation. The standard robot kit is developed to achieve the decided tasks at the robot contest, but is not intended to create new mechatronics systems and design expressions. And also training robots are developed for the mechatronics and engineering education [2]. Students are learned to make them perform such a given task as the line-trace [3] and the inverted pendulum [4]. These tools are suitable for learning the programming to realize the feedback control using sensors and A/D converters, but cannot apply to learn the programming to obtain the design expressions using the mechatronic components.
The mechatronics practice curriculums using a commercially available mechatronics kits [5][6] and a humanoid robot [7] are developed. A robot kit includes several specific parts, by following the instructions in its robot kit, everyone can build a bipedal walking robot without specialized knowledge of robotics and mechatronics, and can control this robot intentionally using a dedicated software. Although it has features for students in engineering education to acquire the technology and knowledge of the mechatronics such as construction of robot, principle of movements, and control algorism, the robot kit has little flexibility to construct a unique mechanism, which should decrease the creativity of students in design education.
In this study, we developed a mechatronics educational tool suitable for studying the design expressions. This tool has the features to make students in design education demonstrate their creativity sufficiently, for example, enough functions to realize unique ideas of design expression, ease of use of these functions, and simplicity to apply for various works.

2 OUTLINE OF MECHATRONICS CLASS

2.1 Concept of education

The mechatronics class (total of 15 times, 180 minutes per once, and one extra for presentation) is composed of two phase: the former, tracks 1 to 8, is a practice to acquire the knowledge and skill of mechatronic devices and PIC assembler program using an original educational tool, and the latter, tracks 9 to 15 and extra, is the design production assignment with a given theme, as shown in Table 1.

Table 1. Mechatronics class curriculum

Track	Term	Content
1	Board production (1)	development of a practice board by etching
2	Board production (2)	soldering and operation check of the practice board
3	Lecture (1)	foundation of mechatronics
4	Lecture (2)	details of the mechatronics devices
5	PIC assembler practice (1)	instruction of equipments, and LED on/off control practice
6	PIC assembler practice (2)	time delay and the usage of switches
7	PIC assembler practice (3)	servomotor driving with PWM signals
8	PIC assembler practice (4)	sensor feedback via A/D converter
9	Lecture for assignment	foundation of interaction design as an interface
10	Assignment work (1)	idea development, sketching, and mockup fabrication
11	Assignment work (2)	mechatronics component examination
12	Assignment work (3)	development of body parts and mechatronics components
13	Assignment work (4)	embedding and assembling
14	Assignment work (5)	programming and operation check
15	Assignment work (6)	final adjustment between software and hardware
extra	Presentation	video recording presentation and the work movement.

Recently, various types of mechatronics products can be found. Product designers are required to design their appearances with taking into account the characteristics of the mechatronics embedded in their products, because mechatronics components, such as batteries, electronic substrates, electronic devices, and wiring, become factors to restrict the degree of freedom of design expression and creativities. That is, students learning in the product design course should experience the design of a mechatronics product after they develop its internal structure and functions themselves. Their students can grow various distinct design expressions using the features of the mechatronics, which is expected to be a precious experience in involved in the product design field in the real world. Therefore, the assignment in this class was set as individual production so that each student could experience whole process of developing a mechatronic system embedded product.

2.2 Teaching tool to learn PIC processor

A 18-pin PIC16F819 processor (Figure 1), Microchip Co., was applied to control mechatronic devices. This processor has two ports: the PORTA and the PORTB. The PORTA is composed of five terminals (RA0 to RA4: #17, #18, and #1 to #3) working as digital input/output (DIO) or analogue to digital converter (ADC). The PORTB is also composed of eight terminals (RB0 to RB7: #6 to #9 and #10 to #13) working as DIO. The #8 or #9 terminals can output PWM (Pulse Width Modulation) signals, which allow drive a servomotor connected to each terminal. As a teaching tool for this PIC processor, a printed circuit board, called the practice board, was developed (Figure 2(a)). The characteristics of the practice board are (1) plain circuit pattern of the power supply to prevent from short between both electrodes, (2) clear distinction between the role of the PORTA and the PORTB: the PORTA is used as input from switches and sensors, and the PORTB as output to LEDs and a servomotor, (3) straight alignment of the PORTA and the PORTB which make it for students easier to understand the relationship between them and the bit operation in assembler, (4) extendibility by plated through holes at the bottom part of the board: students can expand its design expressions via 3-pin connector. The practice board was provided as a circuit pattern film (Figure 2(b)). Students in this class got started by making the practice board themselves using a exposure device and a etching device. The practice board was completed by drilling through-holes on the practice board according to circuit pattern, and soldering electronic parts at each position via through holes (Figure 2(c)).

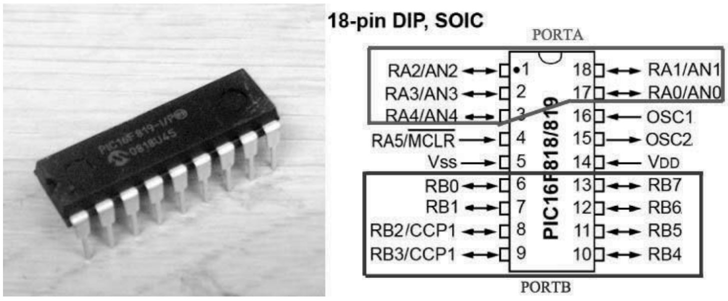
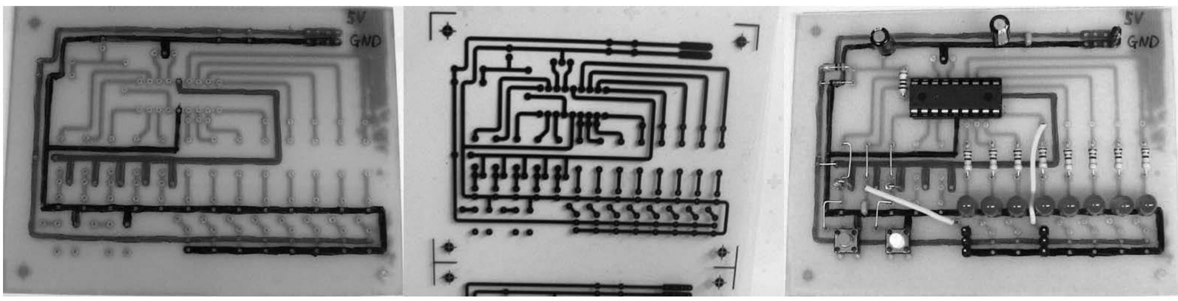


Figure 1. 18-pin PIC16F819 processor



(a) circuit board *(b) circuit patter film* *(c) completed*

Figure 2. Printed circuit board called the practice board and its transparent film

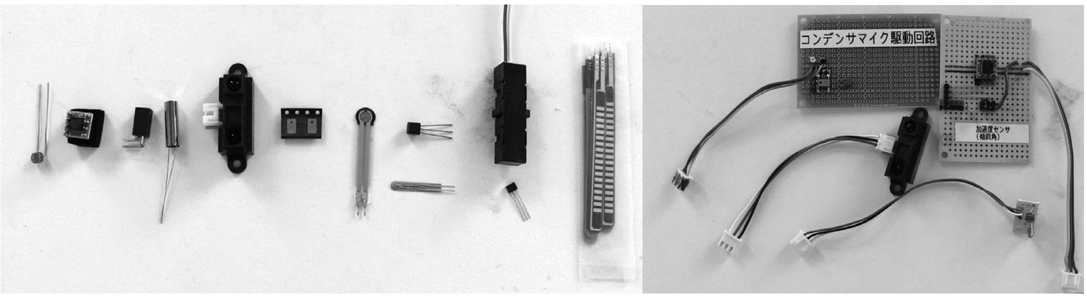
2.3 PIC assembler programming practice

Using the completed practice board, their students learnt PIC assembler programming along with a handbook I developed. The handbook includes sample programs to learn functions for (1) LED blink control by time delay, (2) LED turn on/off interlocking with switches, (3) LED brightness control based on pulse-width modulation (PWM) signals, (4) servomotor driving via CCP1 port, (5) sensor feedback using ADC port, and (6) sequential control of LED blink and servomotor motion with sensor feedback. After learning each sample program, there are several applied questions enable students to improve understanding these functions.

2.4 Lecture of mechatronics

Recently, the mechatronic technologies have been standardized as the Robot Technology (RT). Various persons, even they have no special knowledge about mechatronics, can use these technologies easily. For example, an elementary school kid can construct a bipedal robot oneself along with the direction manual. Therefore, students in the department of design, who generally do not have sufficient knowledge of mechatronics and its elements such as applied mathematics, mechanics, electronics, and control engineering, could apply these technology for design expression because they learned the collect usage of mechatronic components such as sensors, LEDs, and motors, at lectures in tracks 3 and 4, and they also practiced them using the teaching tool in tracks 5 to 8. Figure 3 (a) shows CdS brightness sensor, accelerometer, tilt sensor, micro switch, range sensor, sound sensor (microphone), pressure sensor, thermal sensor, magnetic sensor, and bending sensor, sequentially from the left, respectively. The collect wiring methods of each sensor are presented by sample circuit boards which make it enable to connect to the 3-pin connector on the practice board (Figure 3(b)).

Various LEDs were prepared for design expression elements. A LED sample board was provided to check LED's colour and lighting directionality (Figure 4). Servomotor, DC motor, and stepping motor were also available to express movement as a reaction. Gears could be provided according to student's movement design (Figure 5).



(a) sensor components *(b)sample circuits*

Figure 3. Sensors

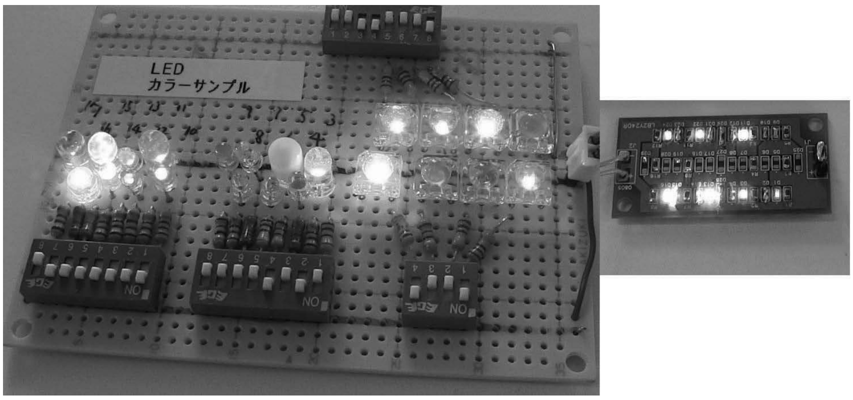


Figure 4. LED sample boards to check colour and directionality

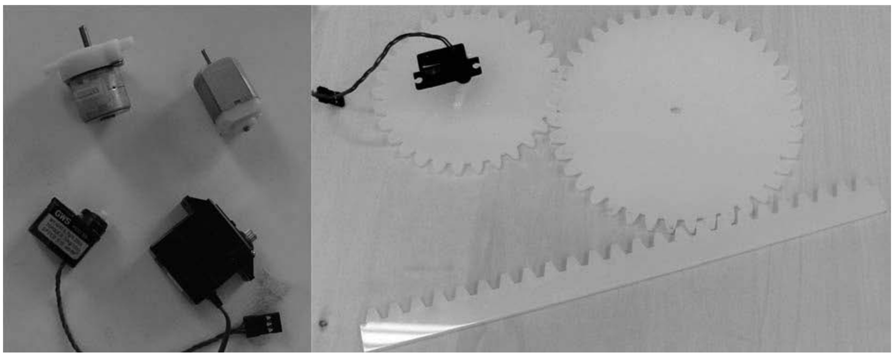


Figure 5. Motors and gears to enhance motions

2.5 Assignment work production theme

At the latter part of this class, students were given an assignment work to develop an actual model of mechatronics-embedded product. Sensibility interface, an instinctive interface that utilize human's biological reactions and body actions instead of logical interface utilizing buttons, literatures, and cursors, is attracting attention now. There are several sensibility interface devices utilizing body actions such as the Wii Remote Controller and the Kinect controller for Microsoft Xbox 360. Mechatronics components are essential to realize functions embedded in these interfaces, and the appearance design should be optimized so as to provide these functions without detracting aesthetic merits. The production theme of this assignment was settled to produce an "interaction design with human actions." Students in this class were intended to propose a mechatronic device to show a reaction against various human actions detected by a sensor. The students should consider which sensor is appropriate to detect a special movement of human action such as holding a hand over, clapping hands, imposing or touching, breathing on, inclining, *et al*. Then they should also examine the optimal arrangement to make the sensor function sufficiently with keeping aesthetic function of the appearance design. The attainment target of the assignment work is to create an actual model, not only a design concept and hard mock-up of proposal.

3 ACHIEVEMENT OF MECHATRONICS CLASS

Table 2 summarizes assignment works of fourteen students (male, 8: female, 6) who took the mechatronics class in 2010. The most used sensor was the pressure sensor which was embedded into four works. This sensor can detect both the grasping force and contacting actions. In the "Light PEN", LED lighting changes according to the force when grasping its pen-like body. The glass weight put on the "twinkle coaster" can affect its LED brightness and colour. In other two works, "caomochi" and "shake BOX", the pressure sensor was used to detect contact.

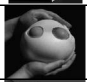
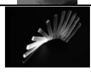
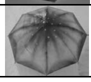
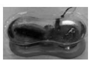
The CdS brightness sensor, the second most used sensor, was embedded into three works. This sensor was used to detect light fluctuation caused by passing over action ("TSUBO" and "Living bath"), including stroking action ("Pa testa"). The magnetic sensor, in the "Put ON" and "Hammy-kun", was used in combination with magnet embedded objects. The accelerometer was applied to the "Auro" so as to detect the body incline of a hand mirror. The sound sensor (microphone) can detect voice and such a wind noise as breathing as shown in the "Rest" and "Key Wing". The micro switch was settled to be turned on when a light weight object, a key holder in the case of "Key Wing", is hooked.

In order to detect "stroke its head" actions, different sensors were used in the "caomochi" and "Pa testa". This means that students designed their works with taking into account both their structures so that each sensor could work collect, and aesthetics of their appearances. The surface of the "caomochi" is applied a human skin like gel to make the stroking force transfer to the pressure sensor. In contrast, the surface of "Pa testa" is covered by a transmissive thin wooden sheet, and a CdS brightness sensor is behind the sheet, which does not make the sensor affect its appearance design. Various LEDs were used in all works, which included three works adopted servomotors, and two works adopted DC motors, simultaneously. There is a DC fan in the "TSUBO". It blows to a flower irradiated by a white colour LED when someone passes in the front. In this case, the reaction is expressed by a flower shadow shaken by the DC fan blowing.

4 CONCLUSIONS AND FUTURE WORKS

In the mechatronics class in the Product Design Course, School of Design, Sapporo City University, I had a mechatronics class using a teaching tool for PIC processor. Learning PIC assembler programs for LED blink control by time delay, LED turn on/off interlocking with switches, LED brightness control based on pulse-width modulation (PWM) signals, servo motor driving via CCP1 port, sensor feedback using ADC port, and sequential control of LED blink and servo motor motion with sensor feedback, students in this class worked on the assignment to develop an actual model of mechatronics-embedded product based on the theme of interaction design to show reaction against human actions detected by a sensor. In the future, I will conduct an advanced mechatronics class focusing on critical fusion of the functionality design and appearance design in the master's course of the Graduate School of Design, Sapporo City University.

Table 2. Summary of assignment works

Title	picture	action	sensor	reaction
"Auro"		incline its mirror	accelerometer	The LED turn-on number changes according to the mirror incline angle.
"REST"		breathe on it	sound sensor	LEDs blink following a pattern.
"Pa testa"		stroke its head	CdS brightness sensor	A LED glows and a servo motor makes the head bow.
"cao-mochi"		stroke its head	pressure sensor	A LED glows, a servo motor winks its eyes.
"Put ON"		put a object on it	magnetic sensor	A LED brightness changes according to the object position.
"Twinkle coaster"		put a glass on it	pressure sensor	The LED turn-on number and colour change according to weight of the glass.
"Key Wing"		hook a key after breathing	sound sensor micro switch	Wings open when breathing. When a key hooked, wings close after LED glowing.
"Hammy-kun"		brush its teeth	magnetic sensor	The LED turn-on number changes by brushing time.
"TSUBO "		something passes over in front of it	CdS brightness sensor	A flower object is shaken with wind from a fan.
"LIGHT PEN"		grasp it with fingers	pressure sensor	The LED turn-on number increases in proportion to grasping force.
"KAZA MI"		call to it	sound sensor	LED blink pattern becomes faster.
"Shake Box"		put a pen in it	pressure sensor	Vibration is occurred by an eccentric DC motor rotation with LED colour changing.
"Nagare-boshi"		rotate it like an umbrella	accelerometer	The LED blink pattern becomes faster according to rotating speed.
"Living bath"		fish pass over	CdS brightness sensor	The LED colour changes.

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