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The Making of a Kinect-based Control Car and Its Application in Engineering Education

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ABSTRACT. *With the popularity of the voice and gesture recognition technology, the kinetic human-machine interface (HMI) of personal computers has become a general trend. As a result, the application of kinetic control is finding its way into various aspects of life. This paper introduces the making of a Kinect-based kinetic control car, which can be remotely controlled by body gestures through the Microsoft Kinect sensor device. The components used will be briefly explained, including a PC, a Kinect sensor, an embedded controller, an interface controller, and a motor actuated device. Besides, the design of a kinetic control hands-on course to equip students with the technical expertise in making a Kinect control car is also proposed. Such expertise includes the structure and functions of Kinect sensor, the programming for the PC-end controller, the wireless transmission protocols and technology, the interface controller principles and technology, and the programming for the embedded controller. Literature review and interviews with the government officials, scholars and industry experts were adopted in analyzing the teaching philosophy, learning background, and teaching content before the course modules and teaching syllabus were finalized.*

Keywords: *embedded controller, interface controller, kinetic control, Kinect sensor*

1. Introduction

Since the advent of Microsoft's Kinect sensor device and its software development kit (SDK), the human-machine interface (HMI) of personal computers has achieved a new level where users interact with their computers through body movements. This new form of HMI has quickly spread to various dimensions including education, medical care, entertainment, sports, exhibitions and performances and in turn led to the creation of numerous innovative applications (Chang, Chen, & Huang, 2011; Filipe, Fernandes, Sousa, & Paredes, 2012; Frati & Prattichizzo, 2011; Lange, Chang, Suma, Newman, Rizzo, & Bolas, 2011; Raheja, Chaudhary, & Singal, 2011). Traditionally, most Kinect applications employ body movements via the Kinect sensor to control a virtual object in software such as a role in video games (Tutta, 2012). The recent trend, however, has been shifting from software to hardware-based applications. The Kinect-based kinetic control car proposed by this paper is such an interesting example.

Our Kinect kinetic control car is modified from an off-the-shelf remote control car. An XBee WiFi module as well as an Arduino controller and an interface controller are fitted inside the car to receive the control signals from the PC and to control the two DC motors (one in the front and the other in the rear), respectively (Amorim Vaz, de Souza Silva, & Sol dos Santos, 2014). Plus the help of a PC and a Microsoft Kinect sensor to detect the human skeleton joints movements, one can remotely control the car to go forward and backwards and to turn left and right.

Nevertheless, the expert knowledge for kinetic control is complex including the use of hardware, design of circuit, controller programming, etc., forming a high learning threshold for technical college students. Therefore, this paper also investigates the design of a kinetic control hands-on course in order to contribute to talent cultivation in this field.

2. The Kinect kinetic control car system

The hardware structure of the Kinect kinetic control car system consists of a Kinect sensor, a PC, an XBee Explorer, XBee Wifi modules, an Arduino UNO controller, an interface controller, and motors (Figure 1). Brief explanations of each component are as follows:

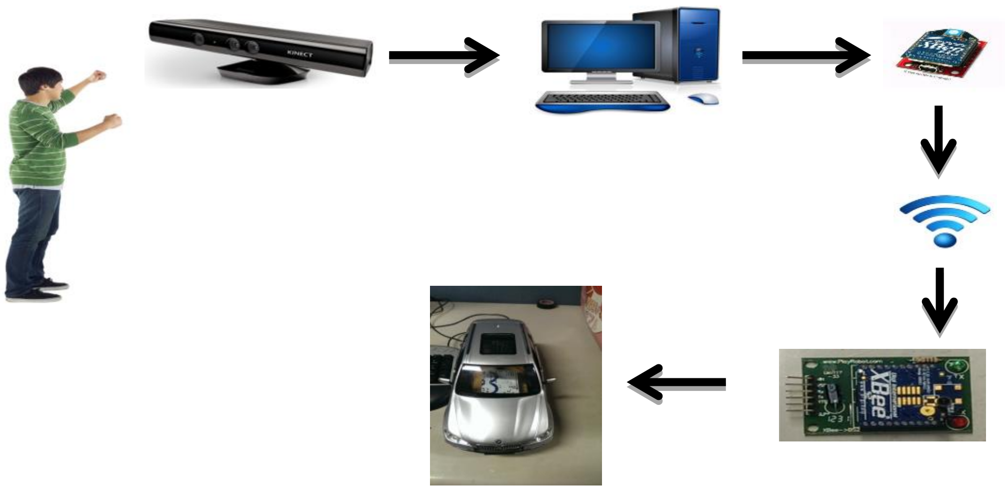

Figure 1: Structure of the Kinect kinetic control car system

(1) Kinect sensor

As Figure 2 shows, there are three cameras inside the Kinect sensor device. The central camera is a RGB color camera that can identify a user's ID or facial features and can also be used in augmented reality games and video calls. The left camera and the right one are the infrared projector and infrared CMOS camera respectively, together forming the 3D depth sensing unit (Microsoft Kinect for Windows Online, 2014) which detects the user's motions. In addition, the motorized tilt base of Kinect sensor enables it to focus track moving objects. An array of four built-in microphones provides noise reduction capabilities; sounds are received and then noise is cancelled through correlation analysis.

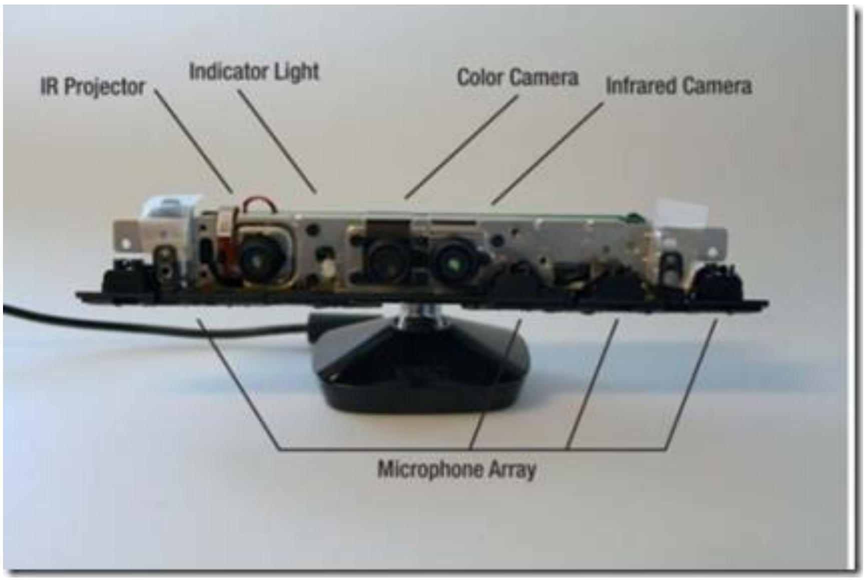

Figure 2: Structure of Kinect sensor device

(2) Arduino UNO controller

Arduino UNO is an open microcontroller board based on the 8-bit ATmega328. It has 14 digital input/output pins which can be connected to various electronic devices, 6 analog inputs and a USB connection. It is hugely popular with engineers and interactive designers because of its affordability, easy-to-use SDK and a wealth of Internet resources.

(3) XBee WiFi RF module

Digi's XBee RF WiFI module uses IEEE 802.15.4 networking protocol and has a 3V working voltage. At the PC end, the XBee WiFi module is connected to the XBee Explorer dongle, which is plugged into the PC's USB port, enabling the controlling signals to be transmitted. At the end of Kinect kinetic control car, the XBee module is connected to the Arduino UNO controller, which receives the signals from the PC. The XBee's Dout pin and Din pin must be connected to the Arduino UNO's Rx pin and Tx pin respectively. Remote control between the

PC and Kinect control car is enabled through point-to-point data transmission. For the transmission to work, XBee modules' parameters must be set in advance using X-CTU. The IDs of the transmitting ends on the XBee WiFi modules must be identical to those of the modules' receiving ends, with the Baud rate set at 9600, as shown in Figure 3. When the Kinect sensor detects the user's control motions, it translates them into control commands, which are then transmitted via the transmitting XBee WiFi module connected with the PC to the receiving XB WiFi module connected with the Arduino controller inside the car. Finally, the Arduino controller relays the commands to the motors for them to actuate accordingly.

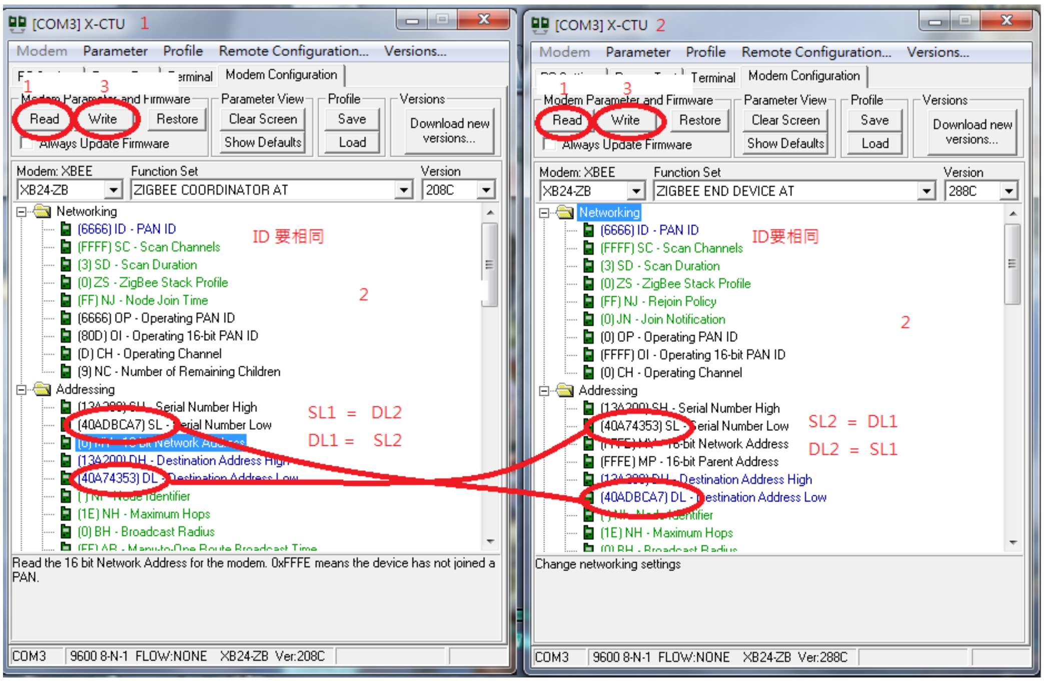

Figure 3 Setting the XBee parameters via X-CTU

(4) Interface board

The interface board contains a dual H-Bridge L293D motor driver IC, which can control the set of two DC motors simultaneously inside the car in any direction. The Arduino UNO microcontroller relays the movement commands from the Kinect to the motor driver IC. To ensure system stability, the power for the MCU and motors must be separately supplied.

(5) Kinect control software

The Kinect application software can set the Kinect sensor's parameters through NUI Library and access the image data, depth image data and audio data streamed by the Kinect sensor array, as shown in Figure 4 (Villaroman, N., Rowe, D., & Swan, B., 2011). The control software defines the human skeleton joints information obtained by Kinect sensor as the control commands. In this way the human body gestures are translated into car control commands (Nghiem, Auvinet, & Meunier, 2012; Xia, Chen, & Aggarwal, 2011). The control commands for the kinetic control car are as follows in Table 1.

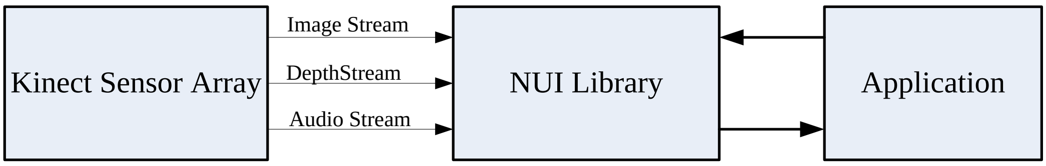

Figure 4: The interaction between the Kinect application software and Kinect sensor through NUI Library

Table 1: Kinetic control car commands

Human gesture	Car commands
Raise the left hand	Go forward
Raise the right hand	Go backwards
Extend the right hand horizontally	Turn right
Extend the left hand horizontally	Turn left
Keep both hands down	Stop

3. The planning and design of a kinetic control hands-on course

To plan the kinetic control hands-on course, literature review was initially carried out to determine the theories and technology about the Microsoft Kinect sensor required for such course, followed by establishing the course’s learning background and objectives. Next scholars and experts from electronics, information engineering, and science education fields were either interviewed or surveyed to determine the teaching background, teaching material content and teaching equipment needed for the course. With the interview and survey results, concrete course content and syllabus were finally formulated, the experimental system designed and the teaching materials prepared. The flow of researching and designing the kinetic control experimental system is illustrated in Figure 5.

This kinetic control hands-on course is to be offered in the fall semester in Taiwan to senior students of technical universities majoring in the electronics, information engineering or related disciplines, with students divided into groups of 2 or 3. Theories and practical skills are equally important for students, thus this course is divided into the fundamental knowledge module and the hands-on training module. The former consists of three themes: introduction to the structure and system development flow of Arduino controller, the structure and sensing principles of Kinect sensor device, and introduction to Visual C# 2010 programming language and the design of

Windows applications. After their completion of the fundamental knowledge module, a written test will be administered to students to measure their learning effectiveness. Moving on to the hands-on training module, students will receive training in 10 units covering from getting familiar with Kinect sensor’s structure and functions to completing a kinetic control car. Instructors may choose to carry out a unit-by-unit assessment of students based on their learning progress. These 10 units are explained as follows:

（1）Controlling the movement of Kinect motorized tilt: In this unit students learn the basic skills of Kinect programming to change the tilting angle of the Kinect motorized tilt through Kinect SDK standard library in application software that communicates with Kinect.

（2）Obtaining the sources of sounds and recording sounds: In this unit students learn to access the audio data streamed from Kinect sensor via application software and to write codes for recoding on Kinect. Then through data analysis, they learn to obtain the transmission angle of audio waves, set microphone parameters, turn on and off the audio stream, set the length of recording, save audio files, etc.

（3）Voice recognition: In this unit students learn to complete voice recognition tasks by using Microsoft.Kinect and Microsoft.Speech components and writing codes. Then they learn how to combine the event handler induced by successful voice recognition with interface circuit to control actuation devices such as lamps and fans.

（4）Color video data processing: This unit features skills for processing and applying color video data, such as turning on/off the color camera, turning on/off the color data streams and registering an event handler, setting image quality, accessing data streams, and saving videos.

（5）Depth image data stream processing: The unit trains students to understand and apply depth image data.

（6）Understanding and applying skeleton tracking function: In this unit students learn to obtain the coordinates of human skeleton joints and relay such information back to software for further application.

（7）Serial communication between the PC and Arduino controller: The unit focuses on the skills for communication between the PC and Arduino controller. Students learn how to connect a PC via a USB port to Arduino controller’s two digital I/O PINs for data transmission (Tx) and reception (Rx) respectively.

（8）Turning on/off a lamp by voice commands: In this unit students learn to control a lamp by using Kinect sensor’s voice recognition combined with an Arduino controller.

（9）Controlling LED signal displays by gestures: In this unit students learn how to control multiple LED displays by different gestures, which are detected by Kinect sensor.

（10）Building a kinetic control car: In this final unit, students are supposed to demonstrate the skills necessary for building a kinetic control car that can be controlled by human skeleton information detected by Kinect sensor. Instructors can assess students' learning effectiveness based on the performance of the kinetic control car they make.

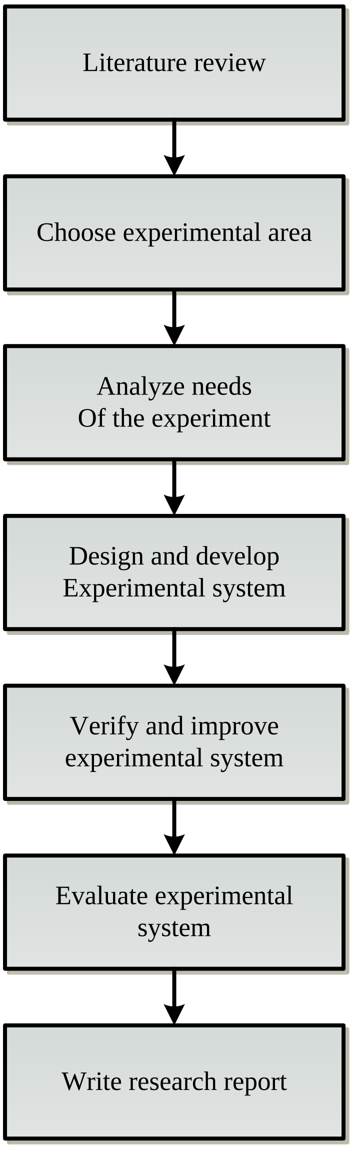

Figure 5: The flow of researching and designing the kinetic control experimental system

4. Conclusion

This paper introduces the technical essence for kinetic control by building a kinetic control car. It also provides a framework for designing a kinetic control training course, which puts equal emphasis on both theories and hands-on practice. By the time students have completed this course, they shall have a comprehensive understanding of Kinect sensor's principles and functions as well as the competence to design the circuit and write the codes for Kinect-based control systems. As

Kinect-based control applications are becoming increasingly commonplace in various aspects of life, business opportunities are abundant. It's time that corporations and universities worked together to develop this industry by commercializing more relevant applications and designing more courses and teaching materials to help cultivate more talent.

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