USE OF EMBEDDED SYSTEMS TO ENGAGE UNDERGRADUATE STUDENTS IN RESEARCH ON MECHATRONICS DESIGN AND APPLICATIONS

Andy S. Zhang
azhang@citytech.cuny.edu
NYC College of Technology
186 Jay Street
Brooklyn, NY 11201

Ali Harb
ccalex1973@yahoo.com
NYC College of Technology
186 Jay Street
Brooklyn, NY 11201

Alex Wong
awong@digilentinc.com
Digilent Inc.
1300 NE. Henley Court
Pullman, WA 99163

Iem Heng
iheng@citytech.cuny.edu
NYC College of Technology
186 Jay Street Brooklyn, NY 11201

Farrukh Zia
fzia@citytech.cuny.edu
NYC College of Technology
186 Jay Street, Brooklyn NY 11201

Abstract: This paper discusses the use of microcontrollers from Digilent Inc. to engage undergraduate students in researches on mechatronics design and applications through hands-on design projects. Mechatronics technology has been identified as the top ten emerging technology of the 21st century. Almost all high tech products made in today are mechatronics products in nature on which microcontrollers are embedded into the products to function as the brain of the products. It is important to introduce the mechatronics technology and its practices into the undergraduate curriculums to prepare students with the knowledge and experience needed for them to seek employment in the areas of product design and development and in high tech manufacturing facilities.

Digilent Inc.'s microcontrollers: ChipKIT uC32 and chipKIT Max32 were being utilized by the students to design mechatronics products such as apple collecting robots and robotic arm manipulators that have been widely used in production lines. Students learned valuable knowledge beyond their traditional disciplines as product design has become a multidisciplinary field that requires members in a design team to posse knowledge in other fields so they can communicate with each other effectively. Undergraduate research activities included the design and integration of effective mechanical systems and electronic systems; building; testing; and programming physical mechatronic products made by each design team.

Keywords: Embedded system, mechatronics technology, undergraduate research projects.

1. Introduction

Embedded systems have become very popular in recent years in product design arena due to the dramatic reduction in prices of microprocessors and microcontrollers. An embedded system is a stand-alone specialize computing device or system designed to perform limited computing functions reliably, securely and cheaply [1]. Robot controller is one of the examples of an embedded system in which the controller perform real-time computing to control the robot in response to surrounding environment.

Traditional approach to product design was confined by disciplinary boundaries. There were seldom collaborations among engineers in different engineering fields. New multidisciplinary approach to product design however requires the engineers to possess broad knowledge and skills beyond their disciplinary fields in order for them to effectively communicate with other members in a design team [2, 3].

This is especially true for many small companies on which an engineer maybe required to perform many tasks that go beyond his/her originally field of study. To help college students to learn the latest multidisciplinary approach to product design, in the fall 2010, the departments of mechanical engineering technology and computer engineering technology introduced a hands-on design project in their respective capstone courses as well as in extracurricular undergraduate research projects. These hands-on design projects contained mechanical design, electrical/electronic design as well as software design components.

In previous studies, various embedded systems such as Compact real-time controller (cRIO) from National Instruments, NXT brick from Lego Mindstorm, and Arduino family of microcontrollers from ATMEL were being used.

In this study, chipKIT uC32 and chipKIT Max32, both provided by Digilent Inc, were being used by students in the machine design course of spring 2013. Students were required to design robots that can be used to collect golf balls on the floor.

The uC32 board as shown in Figure 1 is made of powerful PIC32MX340F512 microcontroller which features a 32-bit MIPS processor core running at 80 MHz, 512K of flash program memory and 32K of SRAM data memory. The uC32 board provides 42 I/O pins that support a number of peripheral functions, such as URAT, SPI, and I^2C ports and pulse width modulated outputs. Twelve of the I/O pins can be used as analog inputs or as digital inputs and outputs [4].

The Max32 board as shown in Figure 2 is made from the powerful PIC32MX795F512 microcontroller which features a 32-bit MIPS processor core running at 80 MHz, 512K of flash program memory and 128K of SRAM data memory. In addition, the processor provides a USB 2 OTG controller, 10/100 Ethernet MAC and dual CAN controllers that can be accessed via add-on I/O shields [5].

This paper presents an initial result of the educational/research project which includes mechanical design, electrical design, and software design.

2. Mechanical Design

The first phase of the design project was the design of mechanical components which include the design of drive train for the robot and the design of the golf ball picking mechanism. Students were required to use computer aided design (CAD) software such as Autodesk Inventor to come up with a virtual design of the robot such as the ones shown in Figure 3. Then students were required to construct a physical prototype corresponding to the CAD models such as the ones shown in Figures 4.

Students were first shown two videos which showed steps that an innovative product design company, IDEO, used when developing new product [6, 7]. Then students were divided into design teams. Each team was required to troubleshoot the two existing robots shown in Figure 4 and find advantages and disadvantages of each robot. Students were asked to perform additional research and come up with their own design of the mechanical system of the robots.

3. Electrical Design

Electrical design involves the study and research on types of motors, sensors, and motor controllers used in robots. This part was very challenging to mechanical engineering students because most of them lacked in-depth knowledge on electronics and electrical circuits. To help students to understand the basics about motors and motor controllers, a test unit as shown in Figure 5 was used to show students why motor controllers were needed to control the speed and direction of the motors.

As indicated in Figure 5, a Pololu TReX DMC01 Dual Motor Controller was used in the test setup. One side of a dual motor controller was connected to Max32 board. The other side was connected to a gearmotor with encoder. A test program was created using Digilent's mpide Integrated Development Environment (IDE) software. Once students learn how to interface motors through motor controllers, students will mount the testing unit on a testing robot as shown in Figure 6 to further study the inter-dependence relations between mechanical systems and electrical system. Finally students will be introduced on how to use sensors to control the robots using the information collected from the sensors. Students will learn how to use different communication protocols such as SPI, I2C, and CAN to interface with the sensors.

4. Software Design

To program the robot to achieve desired behavior, students need to come up with a strategy on software design. First students will be taught to create electrical circuits which contain motors, sensor, and led lights etc, using breadboard and use corresponding sample codes to control each component. Figure 7 shows one such sample code. Once students understand how to control each component, they can develop the code for their robots.

5. Preliminary Results

Students have developed strong interest in working with this hands-on design project. Many students were willing to come extra days to finish their projects. This was an indication that students realize the value of the hands-on projects. This type of project based, research based, hands on activities are an effective way to learn technology which has also been reported elsewhere [8-10].

Many teams were in a process of creating their own robots. For many teams, the robot chassis frame will be made of sheet metal. The sheet metal will be cut by water jet and then bent to shape. Students have begun testing their design concepts using either Tetrix gear motors or Pololu gear motors. Students have also begun testing uC32 and Max32 boards to decide which one to use for their robots.

The project introduces new materials to students that they never saw before. But because these topics are of interest to most students, they were willing to spend more time to engage in research on various topics related to their project.

More work needs to be done in the area of electrical/design and software design. Next step will be for students to test their robots using different sensors and control logic to control the behavior of the robots under a variety of scenarios. This will allow students to fully understand the multidisciplinary nature of product design and to gain important experience in the mechatronic product design.

There is no doubt that this type of design activities are very challenging to the students. One of the considerations was to break down the design project into small components. Some of the components can be taught by professors who teach feeder courses. This will give students more time to understand various topics in different engineering fields and accumulate the knowledge step by step.

More results of students work will be reported in future articles.

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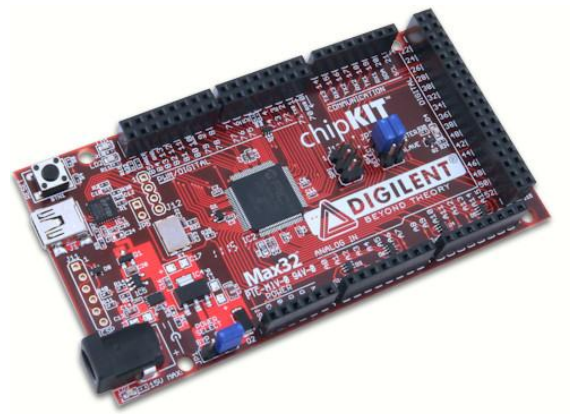

Figure 1. The chipKIT uC 32 Board   Figure 2. The chipKIT Max32 Board

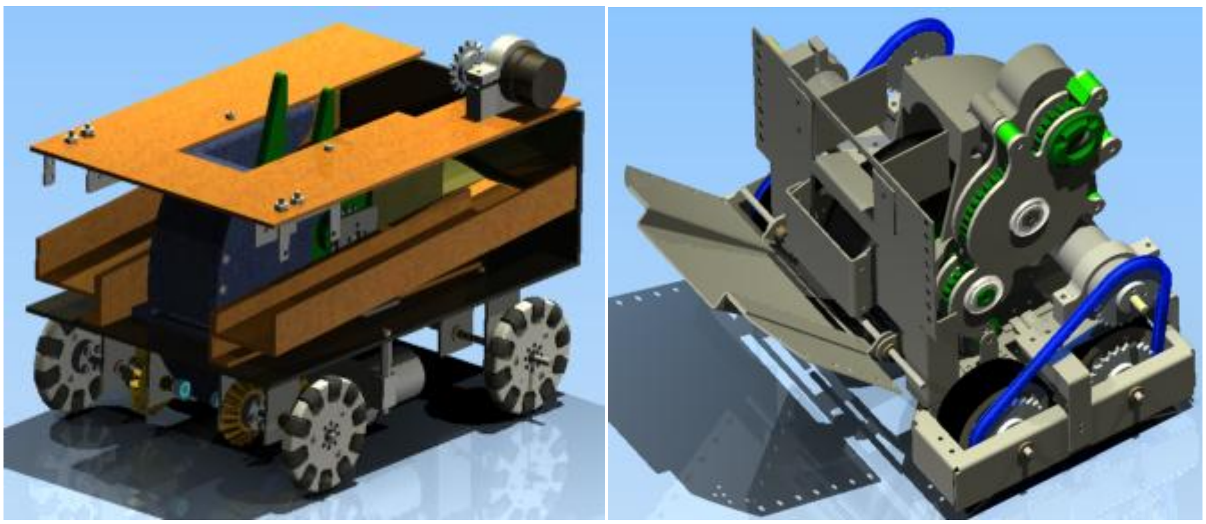

Figure 3. CAD Models 1 and 2

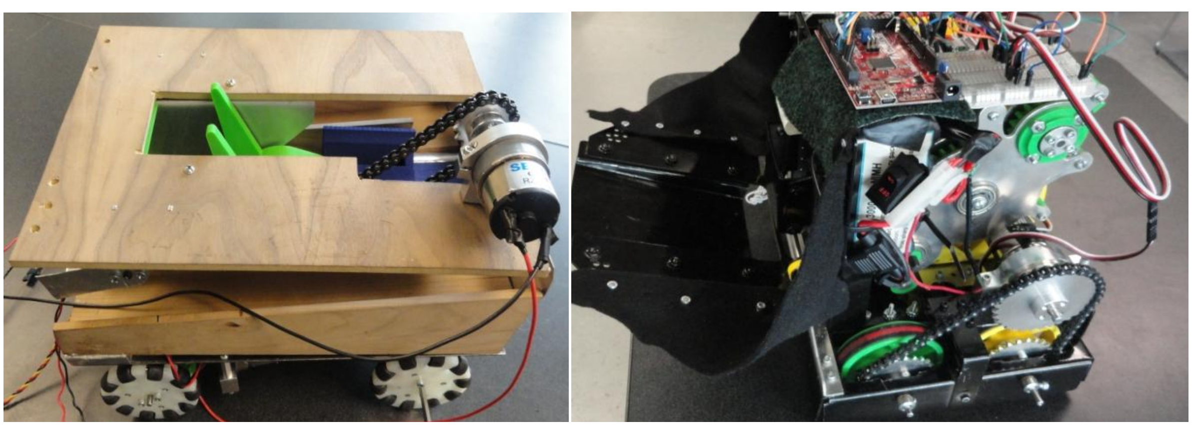

Figure 4. Physical Robot Prototypes 1 and 2

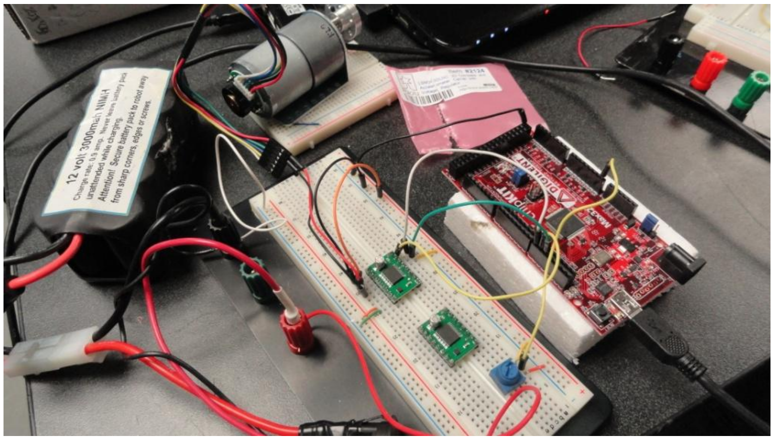

Figure 5. Test Setup to Test Motor Controllers

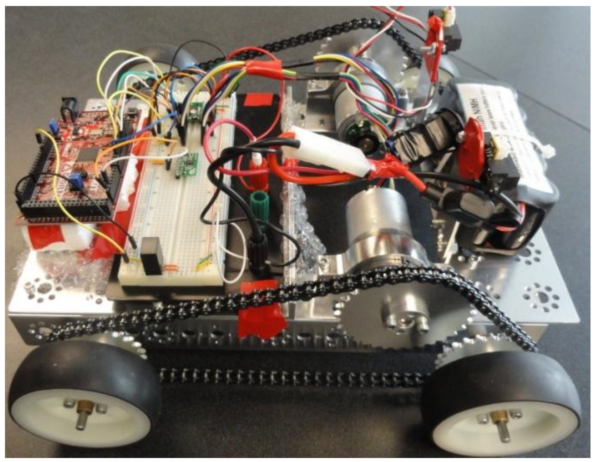

Figure 6. Testing Robot

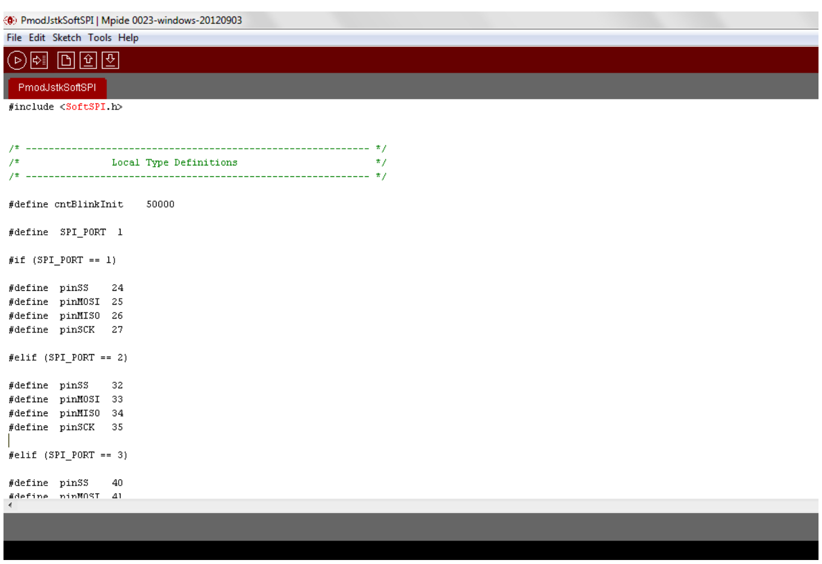

Figure 7. Sample Code