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A Hands-on Robotics Concentration Curricula in Engineering Technology Programs

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A Hands-on Robotics Concentration Curricula in Engineering Technology Programs

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Abstract

This paper discusses the creation of a robotic concentration with four courses to meet the industry demands for qualified graduates in product design and services. Advances in computer technology and electronics have created a new field called **mechatronics**. Nowadays almost all high tech products are mechatronics in nature. Products such as automotive subsystems (such as anti-lock braking systems and automatic steering systems), medical devices, environmental monitoring systems, service and surgical robots are all mechatronic products. The robotic concentration focus on one of the most popular and visible area of mechatronics: ***robotics***. The creation of the four courses: Embedded Systems Fundamentals, Actuators and Sensors, Control Systems, and Robotic Design and Applications is aimed at addressing the important issues of proper scaffolding for the engineering technology students in three engineering technology departments so that students will be able to engage in product design and development using integrated concurrent engineering and multidisciplinary approach.

Introduction

Many US economic activities focus on the product design and developments and US leadership in engineering and technology depends on innovation and inventions in the area of product design and development. Advances in computer technology and semiconductor electronics have created a new product design field called **mechatronics**. Mechatronics treats product design as system design that requires the tight integration of mechanical components, electrical/electronic systems, industrial design ideas, computer-control systems, embedded systems, and intelligent software into the product design and development processes. It also requires engineers, technicians, and designers from various disciplines to possess broader knowledge beyond their specialized fields and to work together concurrently.[1-2] This concurrent engineering and mechatronic design approach, which emphasizes team collaboration, has become the new industry standard in product design and development. Mechatronic technology has been identified as one of the top10 highly influential emerging technologies of the 21st century by MIT's Technology Review and by the International Center for Leadership in Education.[3-4]

Traditional approaches in teaching product design and development in a college or university setting remains along disciplinary boundaries. There are seldom collaborations among different engineering faculties to create curricula that allow students from different engineering fields to work on a multidisciplinary design project that requires the students to collaborate in a systematic manner.

Convergence in engineering requires engineering students such as the mechanical engineering students to possess knowledge beyond their disciplinary field when working on multidisciplinary mechatronics product design and development so that they can work independently or they can communicate with other engineers more effectively and efficiently.

In 2010, a group of faculty members from Mechanical Engineering Technology (MET) and Computer Engineering Technology (CET) departments received a NSF Advanced Technology Education (ATE) grant to introduce mechatronics technology into existing MET's and CET's associate degrees programs. Later, faculty members from Electrical Engineering Technology (EET) department joined the group. The hands-on mechatronic (robotic) design projects created by the faculty members have opened up a new frontier for the students to engage in mechatronic design activities and through which to develop new ideas and new devices/products while in

college. Many students won prices in numerous college level robotic (mechatronic) design competitions using the work of their design projects.

While creating mechatronic projects and design activities and incorporating them into the existing courses in the MET, CET, and EET departments, the faculty members realized the limitations of existing courses that lacked certain aspects of scaffolding elements that their students needed to be exposed beforehand in order for the students to finish their design projects independently and smoothly. As more and more students from MET, CET, and EET programs are engaging in various hands-on mechatronics/robotic design activities every semester, they requested that mechatronic/robotic concentration program be created in each department so that students can be exposed to mechatronics/robotic technology in a more systematic way.

To address the needs of our students, a group of faculty members from the three engineering technology departments (MET, CET, and EET) agreed to work together to create four robotic courses in each department that share the course name and numbers. The new courses will be co-listed in the college catalog. This will allow faculty members from different departments to co-teach the courses thus creating opportunities for students to learn robotic technology from different perspectives. This further creates opportunities and a platform for faculty members and students to collaborate. The four courses that will be created and co-listed and the faculty members will be teaching or co-teaching these courses.

Detailed Design of the Robotic Concentration Courses

The robotic concentration created in the three engineering technology departments focus on one of the most popular and visible area of mechatronics: ***robotics***. The technology innovation in robotics design and development is the most dynamic that represents the latest development of the mechatronics technology. The robotic concentration is designed to address the important issues of proper scaffolding for the engineering technology students of the three departments to engage in product design using integrated concurrent engineering and multidisciplinary approach.

All the courses in the robotic concentration are designated as elective courses for MET, CET, and EET students. They are designed to give those students in the three departments, who want to develop robotic expertise, to acquire needed knowledge and hands-on skills in robotics so they can work as robotic/mechatronics designers or technicians.

The course sequence is designed in a way that allow students to gain knowledge and skills in robotics in a more systematic and natural manner. The first course, Embedded Systems and Applications in Robotics, introduces to students the world of microcontrollers and other embedded systems, the brains of the robots or smart devices. This course covers the use and potential applications of embedded system in various key industries. The second course, Actuators and Sensors Applications in Robotics, introduce to the students the world of sensors, actuators, and their applications. Sensors provide feedback to a robot of its environment or surroundings and actuators provide muscles for the robot to take action or react in response to the changes of its surroundings. The third course, Control Systems in Robotics, covers the control theory so students can elevate their knowledge from making simple robotic systems and interfacing with sensors and actuators to how to control the behavior of a complex robotics system. The last course, Robotic Designs and Applications, provides opportunities for students to actually engage in designing robotic systems for specific applications as they relate to MET, CET, and EET programs' needs.

The brief course descriptions of each course are shown below:

Courses	Brief Course description:
MET/CET/EET 3572 – Embedded Systems and Applications in Robotics	This course introduces students to the architecture and program development of embedded devices with applications to the robotics and smart devices. Hands-on experiments and projects will be included.
MECH/CET/EET 3672 - Actuators and Sensors Applications in Robotics	This course covers actuators and sensors with applications in robotic systems and/or smart devices. Topics include selection of sensors and actuators, and signal conditioning techniques in the design of robotic systems and smart devices.

MECH/CET/EET 4772 - Control Systems in Robotics	This course covers control system theory and application in robotics and/or smart devices. Students are expected to use modern hardware and software tools for prototyping control systems in robotics.
MECH/CET/EET 4872 - Robotic Systems Design and Applications	This course provides an opportunity for students to design and develop robotic and intelligent systems. Students are expected to build and test a robotic system.

For MET department, currently, there are two concentrations in its Bachelor of Technology program: the industrial design concentration and the manufacturing systems concentration. The robotic concentration in MET department will address the important issues of proper scaffolding specific for the MET students who will be working in product design fields using integrated concurrent engineering and multidisciplinary approach or in manufacturing facilities where robotic automation is the key for improving productivity. This is to prepare mechanical engineering students for new challenges in the fast-changing product design and development areas and in modern manufacturing facilities. The new concentration helps those students who want to develop expertise in robotic design and in factory automation.

The creation of robotic concentration is also to address the requests made by ABET's mechanical engineering technology program evaluator and by the MET department's industrial advisory board. They all suggested that mechatronics/robotic technology be introduced in its mechanical engineering technology curricula to reflect the future needs of the industry. A new program objective is added to the department's current Program Educational Objectives which states: "students possess multidisciplinary knowledge and skills" before graduation.

Robotic concentration will also help students in the MET department's manufacturing concentration as most manufacturing equipment such as CNC machines and industrial robots are robotic systems in nature. More and more manufacturing companies claim that robotics is how the advanced manufacturing companies got their job done. We believe that with the introduction of robotic concentration in our B. Tech. program, it will provide our students with well-round hands-on learning experience on the cutting-edge emerging technology and to acquire the multidisciplinary knowledge and skills needed for them to face the real challenge on the jobs whether they are in the fast-paced new product design and development sectors, in the modern manufacturing facilities, in medical device industries, or in emerging R/D enterprises.

The four courses in the robotic concentration will give students necessary exposure to different elements of robotics in a period of four semesters that allow them to start design simple robotic (smart) devices in the first semester and go on to design and build complex intelligent robotic systems in the final semester.

Once exposed to proper robotic technology, students whether they are MET, CET, or EET programs will be well-positioned and better prepared to collaborate and communicate with students and engineers from other engineering fields. Our experience running the mechatronic projects from 2010 to 2017 indicated that students with multidisciplinary knowledge are more willing to collaborate if they can speak and communicate with each other's "engineering language". This makes the collaboration more effective and more meaningful.

Emphasizing Hands-on Design Activities

The robotic curricula emphasize the hands-on learning. All four courses focus on the hands-on learning as engineering profession is really a practicing profession. Many technical knowledge and skills can only be better understood through hands-on activities. They would be able to find these in textbooks. If we did not provide students with hands-on opportunities for them to learn from their mistakes while in school, their first mistake will be made when they work for real companies. As many experience engineering can testify that it takes years for them to accumulate the needed hands-on knowledge and skills in order for them to be successful in their work.

Initial Results

The first robotic course was offered in fall 2016. Arduino microcontrollers were used as the embedded system. When working on the embedded systems students were given a design project that require them to utilize the microcontrollers to control they device they are going to design, fabricate, and test.

All projects include mechanical design, electronic design, and software design. This helped students to realize that product design is a system design not a design of unrelated components.

Students have to work in teams and apply concurrent engineering principles when work on each component and consider its role, its size, and its location in the final product in conjunction with other components. Figure 1 has shown three students' robot design projects when taking the embedded system course. Before making a physical prototype, students were required to produce a CAD model of their design such as the one shown in Figure 2. Figure 3 is a robotic arm designed by one group of students when taking the actuators and sensor course. The arm utilizes three stepper motors.

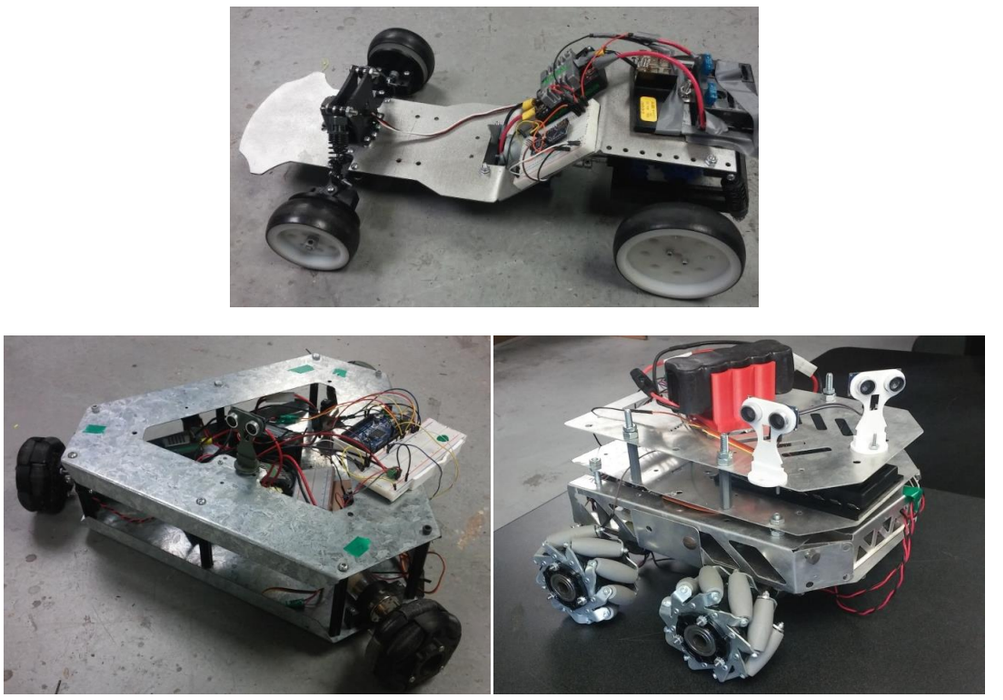
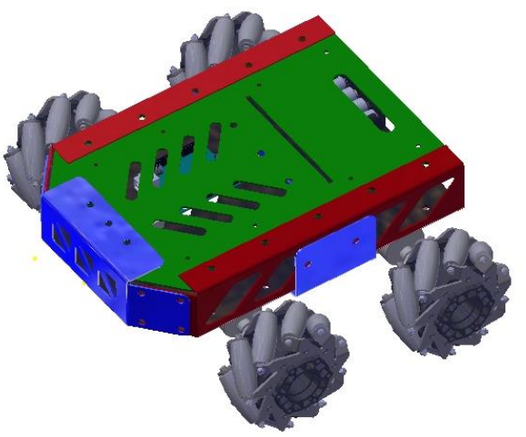
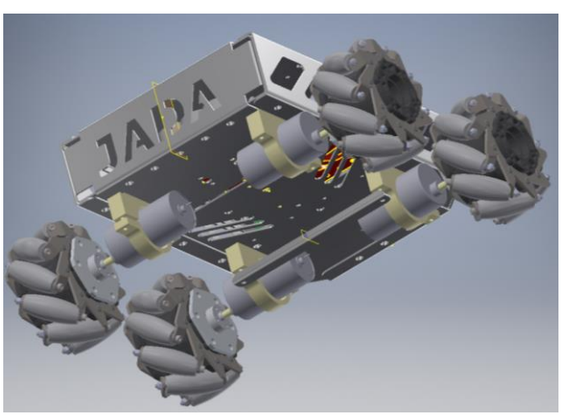


Figure 1 Three Custom-made Mobile Robots Using DC Motors and Sensors



View from Top



View from the Bottom

Figure 2 Computer-Aided Virtual Design Model of Robot Chassis using Sheet Metal

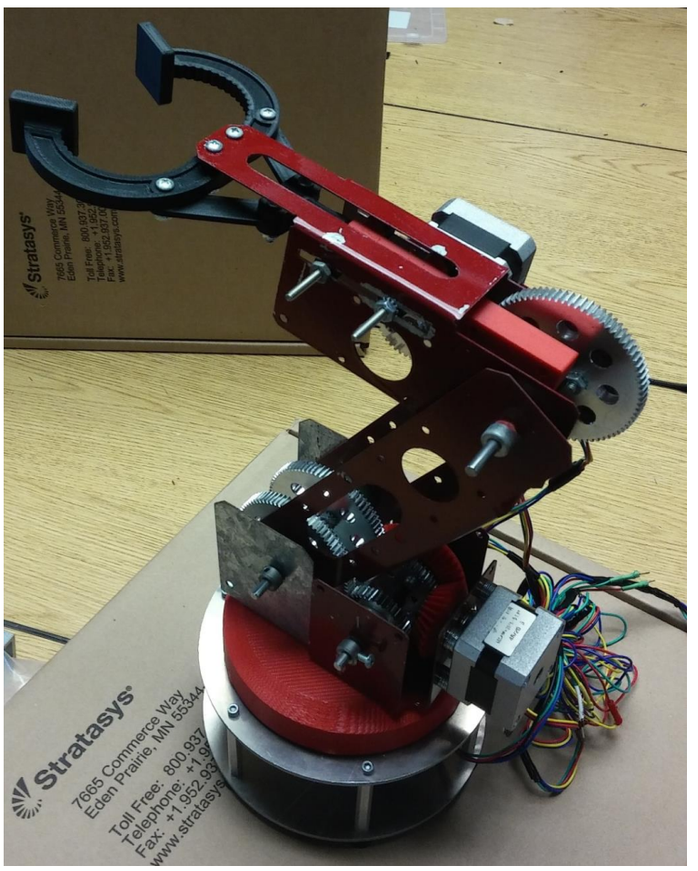


Figure 3 Custom-made Robotic Arm Using Stepper Motors

As can be seen from the quality of student's projects, students welcomed the new robotic courses and were motivated to do more. For most students, programming the robots remains a challenge which is expected. It takes more time for students to gain programming skills. Students were encourage to participate in more extracurricular design activities to continue to sharpen their programming kills as well as other design skills.

Many of the students who worked on various robotic projects presented their work in April 2017 during the Brooklyn Navy Yard Tech Competition. As a result of their work, fifteen students were hired as interns by the companies located in Brooklyn Navy Yard.

Future Work

The creation of the robotic concentration courses helped the college to move away from the traditional paradigm of sequential design within disciplinary boundaries to bring educational practice in sync with industry needs and making hands-on concurrent mechatronic/robotic product design practice with learning and doing going side by side the hallmark of these programs at City Tech.

This approach has been proven to drive much higher levels of performance by empowering each participant; speeding development by eliminating resource bottlenecks; and improving quality and creativity in product development by bringing together multiple perspectives to solve problems and share specialized insights across a range of products [5-8].

With the initial success, the college is encouraging faculty members to create a Bachelor of Science Degree program in robotics and automation. The authors will continue to work on improving the current robotic courses and at the same time work with Brooklyn Navy Yard Development Corp to create internship opportunities for the students who can work in various companies located in BNYDC. This will attract more students to enroll into the college's engineering and technology programs.

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