Enhancing Students' Hands-on Experience and Communication Capabilities through Mechatronics Engineering Program

HOSSEIN RAHEMI, Ph.D.

Professor and Chairman, Department of Engineering and Technology, Vaughn College of Aeronautics and Technology,86-01 23rd Avenue, Flushing, NY, 11369-USA, Email: hossein.rahemi@vaughn.edu

SHOULING HE, Ph.D.

Assistant Professor, Department of Engineering and Technology, Vaughn College of Aeronautics and Technology,86-01 23rd Avenue, Flushing, NY, 11369-USA, Email: shouling.he@vaughn.edu

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Abstract

This paper details the development process of senior-level mechatronics courses which cover comprehensive knowledge of Mechanical, Electronic, Computer and Control Engineering. The overall course objective is to provide mechatronics engineering students an opportunity to work together on software and hardware design with cross-coupled mechanical, electronic and computer subsystems. Meanwhile, considering the cross-disciplinary nature of the mechatronic engineering, we explore various approaches to enhancing students' communication and collaboration capabilities based on their solid theoretical knowledge and rich hands-on experience learned from different courses. Students are required to take the course of Computational Methods in Engineering to intensify their skills of critical thinking and problem solving and they are organized to work on course projects in a team. Furthermore, with the help of faculty members, they develop their course projects or innovative ideas into conference papers or tutorial/postal topics and present them in educational and technical conferences. Their performances working in a team and dialogue with professionals in the field, will build up their confidence and skills for their future jobs in the area of mechatronic engineering.

OVERVIEW

To enhance students' communication capabilities through mechatronic engineering program, this paper will specifically address the following topics

1. Implementing teamwork and classroom presentation in core computational project-based courses.
2. Implementing teamwork and classroom presentation in hands-on project-based senior-level courses.
3. Assisting and engaging students in technical competitions and conference participation.

The implementation of teamwork and classroom presentation in core computational project-based and hands-on core courses not only improve students understanding about problems and solutions related to the engineering systems, but also, strength and enhance their critical thinking and communication skills.

Introduction

Mechatronics Engineering is a relatively new area that integrates mechanical, electronic, computer and control engineering together to design smart products that exhibit precise performance. With the rapid changes in industries as well as the ready availability of low-cost microprocessors, more and more products are becoming mechatronic in nature. Engineers are facing the challenge of having knowledge in multi- and interdisciplinary areas and working in team with people in a broad range of professional disciplines. Therefore, it is necessary to develop new program and courses that provide students with both theoretical knowledge and practical cross-platform skills as well as the strong communication and collaboration capabilities to work with people in different areas.

This paper will present the development process of core courses that can incorporate cross-disciplinary knowledge teaching, computational project-based learning, critical thinking and hands-on experiences into a curriculum through the Mechatronics Engineering program. The development process is based on a model that can improve students' communication, teamwork, and problem solving skills. This model introduces and engages students with the real-world applied problems/projects that incorporate research, analysis, teamwork, and classroom presentation. Furthermore, this study will also address on a process that can enhance teaching and learning effectiveness through core courses in enhancing and achieving those learning outcomes. This paper will specifically address senior-level engineering courses such as engineering analysis (project-based learning), fundamental mechatronics, and advanced mechatronics (hands-on projects) that incorporate teamwork and classroom presentation.

Computational and hands-on project-based learning

The aim is to implement a methodology based on computational and hands-on project-based learning model [1], [2] such that to improve and enhance students' hands-on experiences, problem solving skills and communication capabilities through the new Mechatronics Engineering program developed at Vaughn College of Aeronautics and Technology. Figure 1 shows the graphical model of computational and hands-on project-based learning.

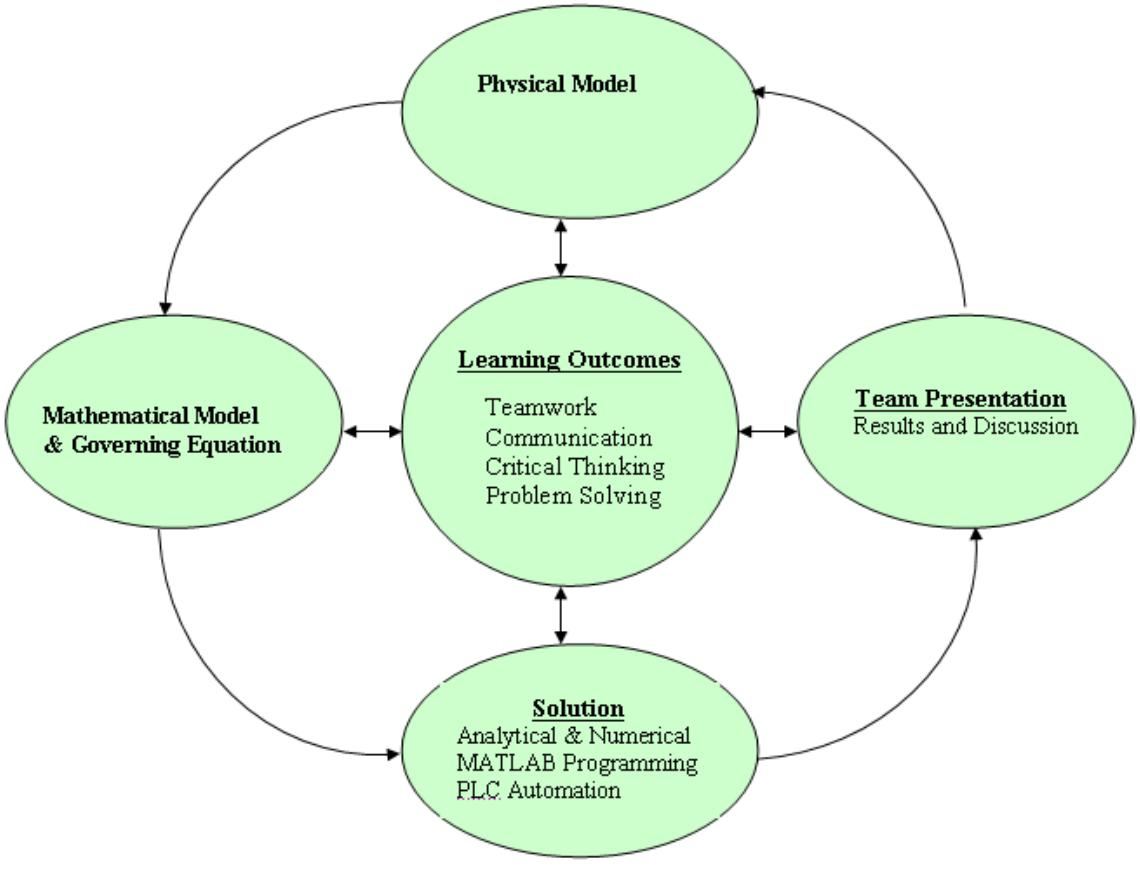

Figure 1: Computational and Hands-On Project-Based Learning Model

To provide students with the skills needed in Mechatronics Engineering, the department has developed a state-of-the-art **Automation Mechatronics Laboratory** to provide students opportunities to gain hands-on experiences and PLC programming skills. This laboratory is equipped with a small-size industrial mechatronics system (IMS) and with eight sub-systems, i.e. Sorting, Assembly, Processing, Testing, Storage, Routing, Disassembly, and Buffering sub-systems. Each sub-system (or the whole system) can be controlled by a programmable logic controller (PLC). (Siemens S300 PLC has been used for this automation control purpose.) In addition, The IMS sub-systems lab course is supplied with the state-of-the-art Virtual IMS 3D Simulation Environment, which enables instructors and students to design & test Mechatronics sub-systems, flexible manufacturing configurations, and control programs before assembly of physical components.

The laboratory facilities are used to teach the course of Fundamentals of Mechatronics - PLC programming and basic concepts of industrial automation. The electronic document, UniTrain-I, developed by the Lucas-Nuelle company, has been exploited to explain the sub-systems and demonstrate their programming process. Through the course and laboratory exercises, students have the opportunity to work with sensors, devices that convert mechanical and physical variables into electrical output signals, as well as a programmable logic controller (PLC), a computing devise that manages and regulates the behavior of a mechatronic system. To the end of the course, students are expected to have

basic knowledge of sensors and devices as well as how they are used in industrial automation. In particular, they should be able to program the PLC controller to solve certain problems in PLC controlled automation lines.

Advanced students' problem solving skills

In an effort to improve and enhance students' critical thinking, problem solving, and teamwork learning outcomes, the engineering and technology department implemented a computational project-based learning model (Figure 1) through both computational method in engineering, and engineering analysis courses. In those courses students will be introduced to numerical methods based on both finite difference and finite element approaches. Students are arranged in several teams, each team is assigned to a technical project with a specific engineering application. The assigned project must be studied and investigated based on available mathematical principles and MATLAB computer programming [3]. The students' projects will be measured based on learning objectives that are identified in the course syllabus and will be graded based on the criteria such as proposal, model development, programming, analysis, report and presentation. Some of those students' computational-based projects were submitted and accepted for publication and presentation in technical conferences [2], [6], [9].
After students have successfully completed the essential courses for Mechatronics Engineering, such as Statics/Dynamics (for physical modeling), Computational Methods in Engineering (for critical thinking, mathematical modeling and numerical method studying), Fundamentals of Mechatronics (for PLC programming and industrial automation), Microprocessors (for digital control using microcontrollers) and Linear Control Systems (for basic control algorithms), students are advanced to senior-level courses in Mechatroncs Engineering. In these courses, system designs, i.e. integrating mechanical, electronic and computer sub-systems into one system, and implementation of the designed systems are discussed.
As shown in Figure 2, a typical mechatronic system can be separated into the following four parts [4], where the sensors provide feedback signals, controllers generate the control signals based on provided regulation algorithm, and actuators are used to produce required forces/torques so that the mechanical systems (or physical systems) can behave as desired.

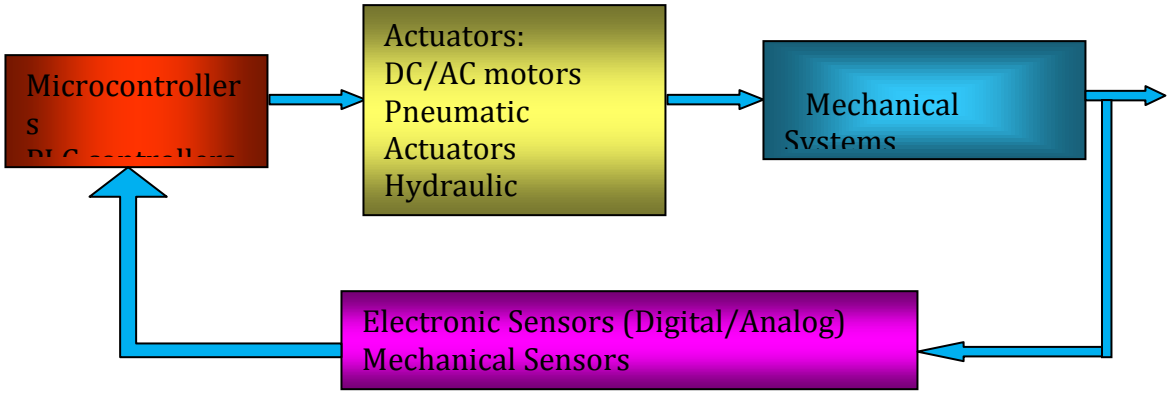

Figure2: A Mechatronic System

The courses start : ɔgramming and PLC programming. Since students have learned the working principle of microprocessors, microcontrollers and PLC programming, as well as programming microcontrollers and PLCs, they are guided to wire some components such as LEDs, LCDs and keypads with a microcontroller shortly.

After the procedure, the working principles of different sensors will be reviewed and further studied, such as positioning sensors (potentiometers), proximity sensors (infra-red sensors), ultrasonic sensors, velocity sensors (tachometers), force sensors, temperature sensors, and light sensors, etc. Especially,

students are required to wire these sensors with microcontrollers, program A/D converter and demonstrate the measurement are correct. (Notice that the difference of the courses from Fundamentals of Mechatronics is that they need to design and implement the measurement system here. Previously, they only need to obtain the measurement from pre-fabricated devices.)

Next step of the courses is to discuss different actuators. Students are supervised to find drivers or build drivers so that they can wire microcontrollers to DC motors, stepper motors and so on. In addition, pneumatic actuators and hydraulic actuators are also discussed in the lectures. Since microcontrollers, sensors and actuators have been studied step-by-step, students are required and encouraged to build some simple closed-loop mechatronic systems, for example, a temperature sensor and fan system or a light tracking system.

The last content of the advanced mechatronics courses is the closed-loop control system design. Since students have learned the principle of control systems, i.e. root loci method and bode plot method, the practical control system design [5] will be discussed here, for example, how to use an operational amplifier to build an analog controller, how to design a control system in discrete-time domain, and how to implement P, PI, PD and PID controller using analog circuits, microcontrollers, PLCs and so on.

Once four sub-systems of a typical mechatronic system, especially the industrial control algorithms, have been studied and implemented, students are required to complete a course project. In the project, students must use sensors, controllers, and actuators to build a mechatronic system. Furthermore, in the project report, students need to clearly indicate how each of four parts works in the system. Especially, the development of the control algorithm, i.e. how the control algorithm is explored to satisfy the system requirements, needs to be described.

The advanced mechatronics courses help students understand how to substantially design a mechatronic system. Besides, the system design and troubleshooting process in physically implementing a control system using microcontrollers, sensors and actuators increase students' capability for practically problem solving.

Students' engagements and activities

In the core courses (computational method in engineering, finite element analysis, fundamental of mechatronics, and advanced mechatronics) students are assigned to projects that are involved with analysis, programming (MATLAB, C++, PLC, and Lab@Soft), report, and presentation. Students' best innovative projects will be selected and assisted by faculty advisors for the publication and presentation in regional, national, and international engineering conferences [6], [7], [8], and [9].

For the past four years the engineering and technology department created many activities to enhance students' hands-on experience and communication capabilities through engineering and engineering technology programs. Some of those activities and engagements can be categorized as follows

- **Industry Connection Seminar:** In Fall 2008, engineering and technology department established an industry connection seminar. This seminar is designed to enhance students' learning outcomes related to communication and problem solving. Given the rapid pace of technological change, the industry connection seminar is intended to assist the students in developing a mind-set that changes in technology are constant and that lifelong learning is necessary to meet future professional challenges. We invite guest speakers to the College to discuss a topic related to engineering and technology.
- **Robotics Club:** Robotics club has been established to motivate students' innovative mind and enhance their hands-on experiences in mechanical and mechatronics engineering programs. The

club is able to develop many innovative robots for both robotic competition and conference publications.

- **Robotic Workshop:** This workshop is given by robotics club to new students to introduce them with the development process of robots and their functionality. Students in this workshop will learn about various sensors, devices that convert mechanical and physical variables into electrical output signals, and actuators.
- **Vaughn College Journal of Engineering and Technology (VCJET):** This journal *is published annually in preparation for the Technology Day Conference.* This Journal includes events/activities of engineering & technology department, student's engagements, robotics competition, mechatronics poster competition, conference presentation and publishes the best student's research papers for the technology day presentation.
- **Vaughn College Annual Technology Day Conference:** The morning session is a meeting with the industry advisory council members. In this meeting the industry advisory members will be updated with annual departmental activities related to programs, accreditations, internships, students' activities and engagement. *In the afternoon session, students present their research and capstone degree projects in a paper format to the industry advisory members (*Sikorsky, RCM-Tech, Rockwell Collins, Pavon Manufacturing Group, FAA, CDI-Aerospace, U.S. Didactic, Int. Communications Group (ICG), Con-Edison), faculty and students from Vaughn College and Colleges in articulation with Vaughn College. Four judges, two from industry advisory members and two from faculty members, will evaluate students work. The top three papers will be selected as the recipient of the best student paper award of this session.
- **Conference Participation and Publication** – Students are encouraged and assisted by faculty advisor to work on an innovative research for their capstone degree project. For past couple of years, students in both mechanical and mechatronics engineering were able to participate, present and publish papers in engineering conferences. The following are list of conference proceedings publications of students' papers from 2009 to 2011.

  1. Daryl Gruar, "**Automation of Hawer Beechcraft B200/B300 Aircraft – CARGO Door"**, presented at the ASEE Mid-Atlantic Conference at ITT-Technical Institute, Oct. 23-24. 2009.
  2. Brian Linhares, Sharifa Happy, *"**Agricultural Improvements through Mechatronics**"* presented at ASEE Mid-Atlantic Conference at ITT-Technical Institute, Oct. 23-24. 2009.
  3. Daryl Gruar, "**Automation Process of "King Air" Aircraft-Cargo Door Design",** presented at the ASEE Conference for Industry and Education Collaboration (CIEC), Palm Springs, CA, February 3-5. 2010.
  4. Shazim Baksh, "**Finite Difference Impulsive Response Analysis of a Frame Structure – A MATLAB Computational Project-Based Learning**", proceedings of the 8th Latin American and Caribbean Conference for Engineering and technology {LACCEI), Arequipa, Peru, June 1-4, 2010.
  5. Brian Linhares, "**Mechatronics in the Advancement of Public Safety Control**", proceedings of the 8th Latin American and Caribbean Conference for Engineering and technology {LACCEI), Arequipa, Peru, June 1-4, 2010.
  6. Marvin Blackman, Shahidul Islam, Joseph Kamel" **Innovative Cargo Screening Using a PLC System**" Proceedings of the ASEE St. Lawrence Section, Excelsior College, Albany, NY., March 18-19, 2011
  7. Marvin Blackman, Shahidul Islam, Joseph Kamel" **Counterbalance Transportation** " Proceedings of the ASEE Annual Conference, Vancouver, Canada, June 26-29, 2011.

8. Brian Linhares, "**Mechatronics in the Advancement of Transportation Security**", proceedings of the 9th Latin American and Caribbean Conference for Engineering and technology {LACCEI), Medellin, Colombia, August 1-4, 2011.
9. Marvin Blackman, Shahidul Islam, Joseph Kamel" **A PLC Automated Security Checkpoint**" Proceedings of the 9th Latin American and Caribbean Conference for Engineering and technology {LACCEI), Medellin, Colombia, August 1-4, 2011.

- **Robotic Competition** - In past three years Vaughn College Robotics teams were active participant in both national and international Vex Robotics World Championship competition. On November 20, 2010, two groups (VCT1 and VCT2) of Vaughn College robotic team (Brian Linhares, Chandra Mauli, Marlon Medford, Kinlok Poon) participated in VEX robotics competition at the California University of Pennsylvania. The teams won the competition with 2nd and 3rd places, respectively.
- **Poster Competition** – Students in both engineering and engineering technology programs are assisted and encouraged by faculty advisors to present their innovative research project in poster competition of technical conferences. For past couple of years our students in mechatronics engineering and mechanical engineering technology were able to participate in regional and national poster competition of American Society for Engineering Education (ASEE) and international poster competition of the Latin American and Caribbean Consortium of Engineering Institutions (LACCEI). In LACCEI 2010, our students were selected as the recipients of 2nd and 3rd place achievements award of the LACCEI poster competition.

Internship programs and industry involvement

Internship program is a key part of an engineering curriculum to prepare students for the workplace. For past several years, our students were involved with both summer and during-year internship programs with top engineering companies such as Sikorsky, Northrop Grumman Corporation, Lockheed Martin, RCM-Tech, Rockwell Collins, Federal Aviation Administration (FAA), and MTA. In summer 2011, two of our Mechatronics Engineering students participated in a NASA internship program at the Goddard Space Flight Center in Greenbelt, MD. They worked on a project related to design and development process of a robotic arm for use on the International Space Station. This project provided them a greater appreciation for engineering education and expanded their hands-on and carrier-building experiences. As a result of those internship programs, many of our graduates are currently working with those industries and as new advisory members for our programs, assisting our current students in pursuing internship with those companies.

At Vaughn College the industry advisory members have pivotal role in the program delivery and students' success. The industry advisory members work closely with faculty members of engineering and technology department in new course offering and program modification. Their valuable recommendations and comments will continuously make our program delivery stronger and more competitive with the growing demand of today's technology. Furthermore, the close partnership with these industrial companies, such as NASA, Sikorsky, Northrop Grumman Corporation, Lockheed Martin, RCM-Tech, Rockwell Collins, Pavon Manufacturing Group, FAA, CDI-Aerospace, U.S. Didactic, Con-Edison, and MTA, allowed our students to explore an internship opportunity with top engineering enterprises. These internship programs provided our students with the needed career-building and hands-on experiences and a mind-set to adapt the fast changes and challenges in technologies.

Conclusions

In this paper, we have discussed the development of the Mechatronics Engineering program at Vaughn College of Aeronautics and Technologies. In addition to traditional programs, the new curriculum and course arrangement address on students' hand-on experiences and collaboration and communication capabilities. Besides, we have industry involved in the departmental events, resulted programs that satisfy today's industry technological demands and produce graduates who are well prepared for both workplace and graduate study. In particular, internship and capstone degree project provide our students with valuable hands-on and carrier-building experiences.

For past several years, our students participated in many technical conferences, competitions and internship programs. Through all, our students were engaged with projects that not only required implementation of state-of-art tolls and technology but also to enhance student's critical thinking, problem solving, teamwork, leadership, and entrepreneurship activities. More than 90 % of our engineering and engineering technology graduates were able to land an engineering position immediately after their graduation (Sikorsky Aircraft, Northrop Grumman Corporation, Lockheed Martin, RCM-Tech, Rockwell Collins, Pavon Manufacturing Group, FAA, CDI-Aerospace, Con-Edison, and MTA) and many others were able to start their graduate work in well-known graduate schools (Virginia Tech, Texas A&M, Columbia University, City University of New York, and etc.).

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[6] Daryl Gruar, "**Automation Process of "King Air" Aircraft-Cargo Door Design",** presented at the ASEE Conference for Industry and Education Collaboration (CIEC), February 3-5, 2010, Palm Springs, CA.

[7] Brian Linhares, Sharifa Happy, "***Agricultural Improvements Through Mechatronics***" presented at ASEE Mid-Atlantic Conference at ITT-Technical Institute, Oct. 23-24. 2009.

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