Integrating Open Source Resources in Robotics Education

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Abstract

The open-source movement has already revolutionized a number of industries by empowering end-users to contribute to the products that they need and want, and fueling grass-roots development of projects in completely new areas, as well as their continual improvement. Robotics is the branch of mechanical engineering, electrical engineering and computer science that deals with the design, construction, operation, and application of robots as well as computer systems for their control, sensory feedback, and information processing. The nature of collaborative works in Robotics over multiple engineering and science disciplines makes it perfect for open source, which not only leverage minds much greater than ours on specific fields, but also connect college students, industrial developers, hobbyists, educators and researchers.

This paper is about how to integrate open-source resources into robotics engineering technology teaching. The case study is an embedded system course that benefited from open-source software and hardware resources. The course project was to target a robot competition at a national student conference. The students use collaborative platforms such as GitHub, Webex, etc. to communicate with and get help from experts in navigation, programming, circuits design, CAD modeling, etc. They also use many open source resources such as grabCAD, Github, etc. so that they design and develop their robots on predeveloped and tested work that are made available by others. This greatly reduced the development time and improved project quality. This also got them familiar with what industries are doing in project developments[1][2].

Introduction

Embedded System Design is a core course of Robotics and Mechatronics Engineering Technology program of Central Connecticut State University. It covers hardware and software design for higher-end embedded systems development. Includes structured laboratory exercises in programming, peripheral interfacing, device driver implementation, real-time operating system, structure programming, task scheduling, simple digital signal processing (DSP), and other related topics. In spring 2016, the course was redesigned using PBL (project based learning) model. PBL is a student-centered learning model in which students learn about a subject through solving an open-ended problem. Students learn domain knowledge and problem solving skills through the project. This model also promote team work and communication skills.The goal of this year's project was to design a micromouse robot for 2016 IEEE Region 1 annual student conference micromouse competition on April 16, 2016. A Micromouse is a small robot vehicle that is able to navigate its way through an unknown maze. It is autonomous, battery-operated and self-contained, encompassing computer technology, robotics, and artificial intelligence. The main challenge for the MicroMouse designers is to import the MicroMouse with an adaptive intelligence which enables exploration of different maze configurations, and to work out the optimum route with the shortest run time from start to destination and back. In addition, the MicroMouse must reliably negotiate the maze at a very high speed without crashing into the maze walls. Students in the class formed three teams to work on their micromice. Open source resources were introduced to teams and used in the project.

Open sourse based PBL model and its application in the course

There are four reasons that open source resources were integrated in the PBL model of this course. 1. Open source resources are readily available in software, hardware, and mechanical systems; 2. Open source is more and more popular in hobbyists, academia, and industry;[3] 3. Entrepreneurs and companies are using open source resources in research and development;[4] 4. Technologies such as Webex and Github made it possible to include human which is the most flexible and important part of the open source resource[5]. Figure 1 shows the PBL model for this course divided into four stages.

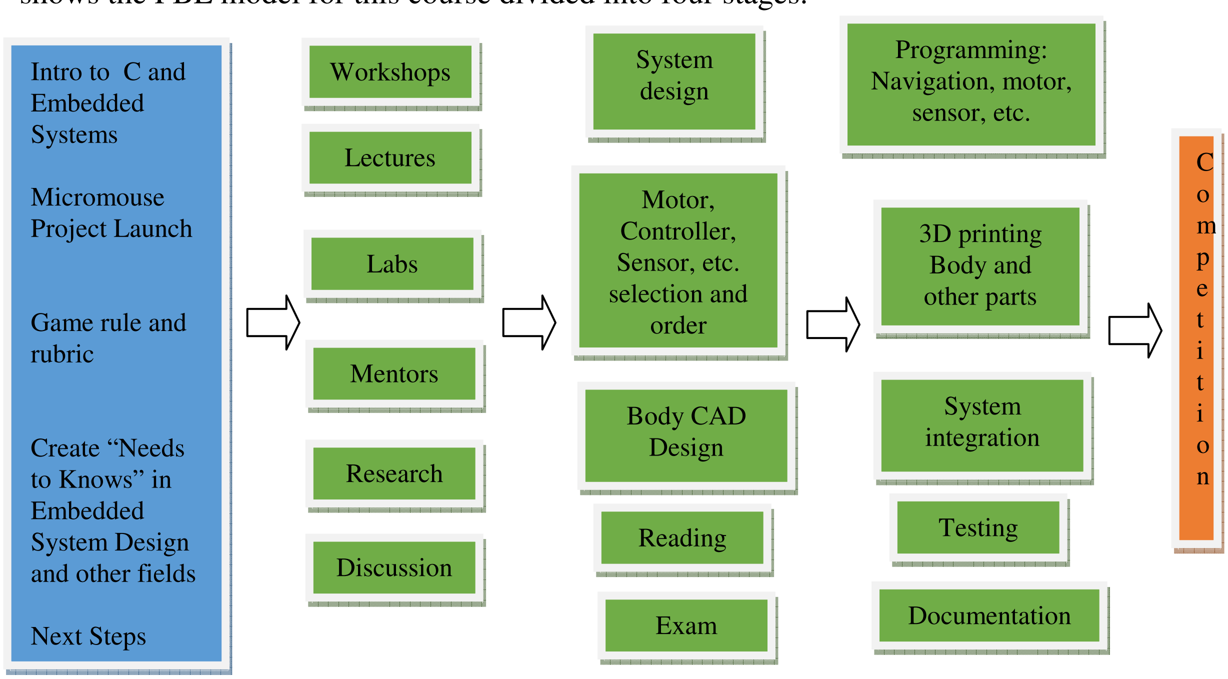

Figure 1. Process and components of the course PBL model

For students, MicroMouse robot competition has always been a focal point of the conference because it provides a playground for participating students to apply their knowledge of science, engineering, and technology. It also promotes teamwork, creativity, leadership, and communication skills. And above all, it is fun!

In the beginning of the class, introduction to C language and embedded systems was given. Micromouse project was introduced to the students. Students were asked to study game rules and the score rubric. They were also asked to do a study on previouse years' micromouse design and generate a "needs to knows" list for the project. In the list, they identified what were among embedded system and what were not. They also discussed what they already knew and what need to be learned. This gave them the guidance about what to do next.

In the second stage, more lectures about embedded systems were given. Three options of controllers were presented to the students. They were Ardruno Uno, Respberry Pi, and Tiva C Launchpad. The online workshops, labs, and open source communities were introduced to the students. Students did research and study those resources as teams.

Three workshops were arranged to help students to be familiar with open source resources and the Micromouse design. The first workshop was about robotic hand design and its open source resources. The presenter was invited to give the workshop on campus. Students learned the current status of open source mechanical systems, 3D printing, and its application in a robotic hand design. The other two workshops were conducted as distance learning through WebEx due to the availabilities of the presenters. A Micromouse design expert ran the second workshop and gave in depth introduction to micromouse design. Students learned overview of the game, motor and sensor choices, micromouse motions, and navigation algorithms to solve the maze. The third workshop was about collaborative development using Github with an example of development of a commercial product GoPiGo robot. All three workshops had Q&A session to engage students and address their questions. The workshops greatly helped students on solving project related problems with real world examples and applications.

In addition to the help of the professor, three volunteer mentors were available to help them about programming, circuit design, simulation, etc. through Github, email, or tele-conference. Students were encouraged to help and teach each other in the team and between teams

In the third stage, one team chose to use Tiva C Launchpad, one team chose to use Arduino Uno, and the third team chose to use GoPiGo robot with Respberry Pi. The decided and ordered their motors, sensors, and other components. They designed their Micromice in SolidWorks. They also decided navigation strategy and motion control.

In the last stage, they worked on programming on sensor, motion control, and navigation, etc. They fabricated components such as chassis and wheels through 3D printing. They assembled components together and completed wiring. They built a small portion of the maze and tested their Micromice in it.

Figures 2 through 4 show that students were testing their Micromice in the partial maze.

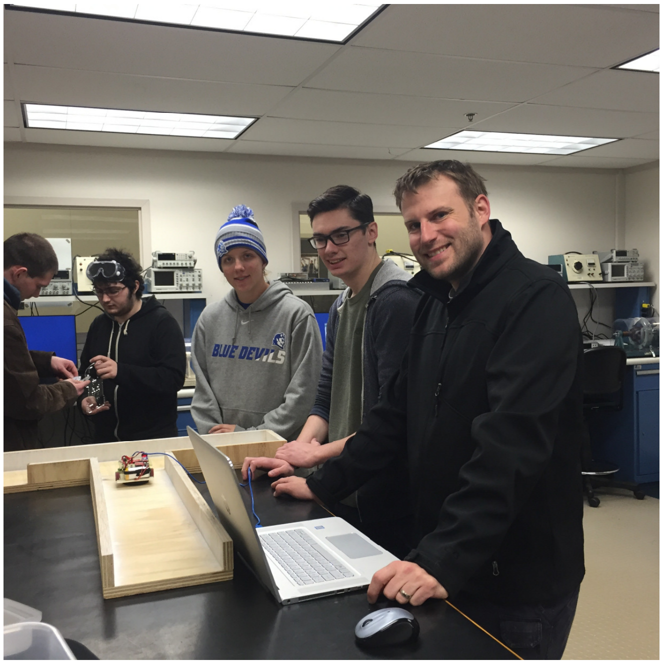

Figure 2. Testing of Micromouse with Tiva C Launch Pad

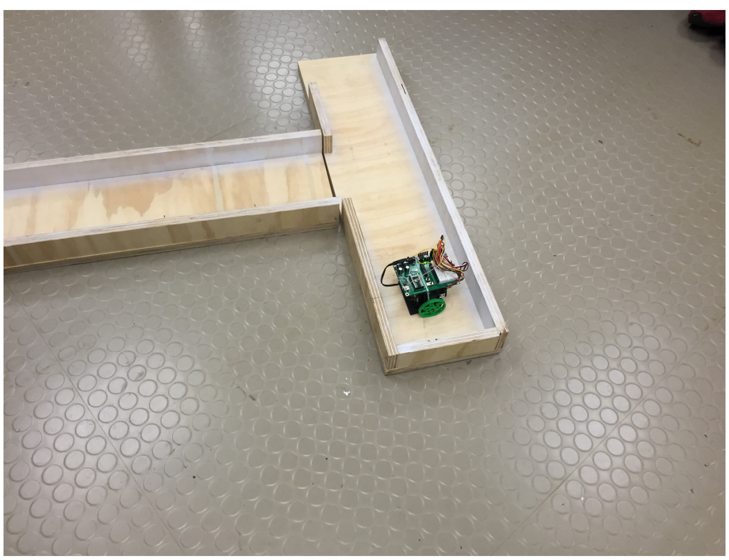

Figure 3. Testing of Micromouse with Ardruino Uno

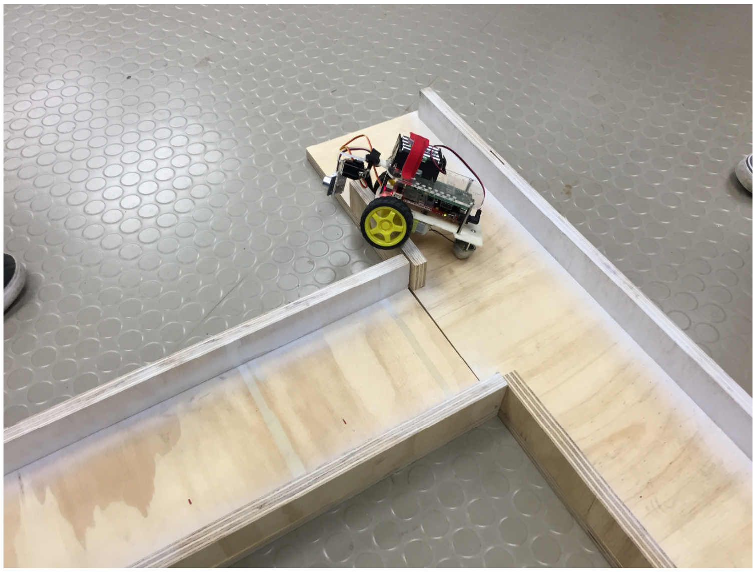

Figure 4. Testing of Micromouse with GoPiGo with Respberry Pi

Figure 5 and 6 show CCSU micromice during the 2016 IEEE region 1 student conference micromouse competition.

Figure 5. Micromouse Competition in the real maze

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Figure 6. CCSU micromice and team members

The results

Two teams developed and built the Micromice from scratch. One team used the GoPiGo kit with customized parts and focused on programming. All three Micromice had their sensors (IR or ultrasonic) and motors (DC or Servo) working well. However, they all had issues in making good turns. The main reason is that it was the first time they participated the competition. The learning curve was high and the time was short. Most of the time was spent on developing hardware and very little time left for programming and testing. But it built the solid foundation for the same course next year for the competttion

Even without wining the competition, all students learned about embedded system well through designing and building a robot. It reflected the foundation of PBL: leaning by doing. The project's target as a competition excited and engaged them from beginning through the end of the project. The integration of open source resources greatly improved their project development speed and quality. They were not only leaned with a professor, but also the whole open source community.

Conclusion

This paper talked about how open source integrated PBL model could significantly improve student leanring interests and outcomes. It turned the traditional professor-student teaching-leanring model into professor guided open source integrated PBL model which is more efficient and acceptable to the students. The method can be readily applied to other robotics courses. Competitions are good choices for course projects. Those projects might take longer time than expected.

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Biographies

Haoyu Wang is currently an associate professor of Robotics and Mechatronics Engineering Technology of CCSU's School of Engineering, Science, and Technology. He received his Ph.D. in Mechanical Engineering from Syracuse University and holds Professional Engineer's license in Connecticut. He co-organized many robotics competitions including IEEE (Institute of Electrical and Electronics Engineering) Micromouse and BEST (Boosting Engineering, Science, and Technolgy) at CCSU. He served as advisor for robotics teams in IEEE Micromouse and Trinity Firefighting. He is working with his IEEE colleagues on a robotics education program to promote robotics education and collaboration on open source hardware and software in Connecticut. His teaching and research are in robotics, injury analysis, metrology, and manufacturing systems.

Biao Zhang is currently the Chapter Chair of IEEE Robotics and Automation Society in Connecticut, Co-Chairs of the IEEE RAS Chapters and International Activities Committee (CIAC). He developed and launched a series of teen robotics workshops, "Make a Robot with Raspberry Pi and Scratch" for 6th to 8th grade students. Volunteers, including college students, robotic hobbyists, IEEE professional members, public school students and teachers, from 14 different Connecticut organizations, were trained prior to the workshops. He served as judge for various robotics competitions, such as First Lego, VEX and International Firefighting Robot Competition. And he is also a research scientist in Mechatronics and Robotics Automation. He received his Ph.D. in mechanical engineering from University of Notre Dame. His research interests include vision-guided robotics, 3D vision, robotic force control assembly, design of experiment optimization, automation on material handling, and human robot collaboration. And he also served as workshop chair, technical session chair, program committee member and technical committee member for several IEEE conferences.

Paul Resetarits is currently a full professor of of department of Manufacturing and Consturction Management at Central Connecticut State University. He is an expert in CAD, Lean Management, and Qaulity . Dr. Resetarits has over 30 years of experience as an consultant, researcher, and educator.