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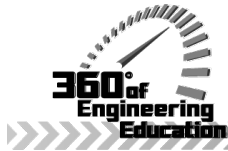
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A Collaborated Process with a Wireless Autonomous Vehicle at its Center

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Introduction

According to a study by Marken and Lewis¹, 46 percent of 1550 degree-granting post-secondary institutions report that over one million high school students took courses for college credit within a dual enrollment program during the 2010-2011 academic year. This indicates that there are more and more high school students interested in studying at post-secondary institutions. It presents opportunities for community college and university engineering and technology programs to recruit already interested students to become majors.

This project used an autonomous vehicle designed and manufactured by faculty at a local university and community colleges to provide interest to students in embedded controls. The vehicle also met a need that a school system had for up-to-date automation and robotics equipment. It is hoped that the results of this collaborative effort will lead more high students to take an interest in STEM related fields to sustain the nation's need for additional young people to enter the career fields of sciences, engineering, and engineering technology, and also improve these students academic abilities in a robotics and automation.

Developing partnerships between public schools, community colleges, and universities are critical for students to achieve success in STEM programs and successfully transition into STEM-related careers. Based on the number of participating students and institutions described by Marken and Lewis, one area of partnership is dual-enrollment agreements between the secondary and post-secondary institutions. Another important aspect is the use of common equipment that engineering and engineering technology programs can successfully adapt for common technology instruction. This project employed of a single, flexible, and expandable technology training platform that can provide the continuity of a learning environment and benefit all levels of education economically. This paper presents the results of how one university senior capstone project grew into collaboration between university departments, a community college, and a secondary high school.

Background

As in many states, the Commonwealth of Virginia requires public schools to provide the opportunity for high school students to take college classes and earn an associate degree concurrent with a high school diploma.² School boards have been creating dual enrollment partnerships with post-secondary institutions to accomplish this end and as long as the high school teachers have the appropriate credentials, students can earn credits at both institutions from classes taught at either setting.

Collaboration between institutions is an important part of the dual-enrollment process. The development of these partnerships is enhanced through the use of common hardware to teach STEM courses related to engineering and engineering technology. The universities, community colleges, and the public schools in this collaboration each have similar goals, since each of them teach robotics, embedded systems, and other supporting technology courses. This

instruction can teach a great deal of the same common material at the different levels. One of the goals of the collaborative process is to build on what instructors at each previous level are teaching, and then further the students' education without having to cover the same topics again. Figure 1 depicts the relationships between the technology platform described in this educational project in the high school, community college, and university levels.

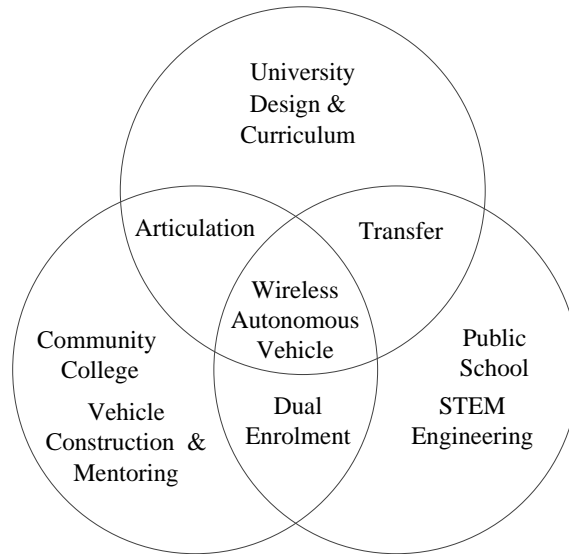


Figure 1. Collaborative Relationships

The Autonomous Vehicle

The concept for the development of a laboratory platform derived from an engineering technology student's senior design project at a four-year institution. Using the faculty member's advice, the students designed and constructed a vehicle capable of being controlled wirelessly, using a microcontroller development board, and work autonomously. The microcontroller board used in this project was previously designed and developed at the university through a funded grant by the National Science Foundation. The board has been used at the university to teach three related embedded systems design courses.

Like many student projects, the design of the autonomous vehicle began with the restrictions of budget. The controlled vehicle was constructed of materials that could be purchased locally and was manufactured using common laboratory tooling. The final product was designed to meet the objectives of (1) having a low cost, (2) offer various payloads, (3) incorporate a Lithium-Ion battery for power, and (4) be autonomously controlled using a manual wireless controller. Commercial-off-the-shelf parts included a gear box, motor, tracks, and wireless camera. See Figure 2.

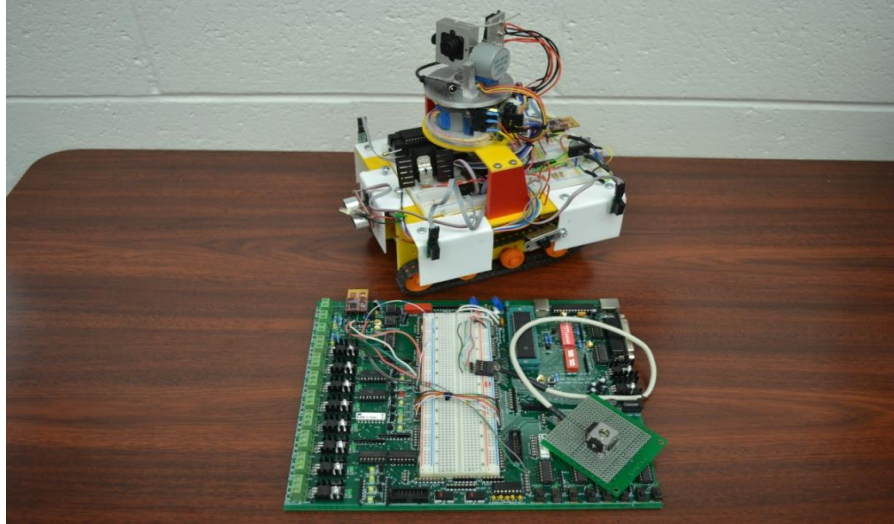


Figure 2. Student's Senior Project Vehicle

The wireless communication is accomplished using the Microchip® MRF24J40MA module³ that is a transceiver that uses a radio frequency of 2.4 GHz and follows IEEE standard 802.15.4™. It comes packaged in a surface mounted module with a built in antenna. The module is compatible with the Microchip software stacks for ZigBee® and other common wireless protocols. The module communicates with the microcontroller using the SPI protocol⁴, which requires only three pins – clock, input data, and output data. The module is FCC compliant and has a range of up to 400 feet, according to the Microchip® datasheet. The vehicle uses an analog wireless video camera that relays video from the vehicle to the command center. The camera uses standard stepper motors to position it horizontally and vertically for a view of the vehicle environment as it travels on its journey. The video camera uses a separate composite video transmitter that also transmits on the 2.4 GHz wireless frequency. See Figure 3.

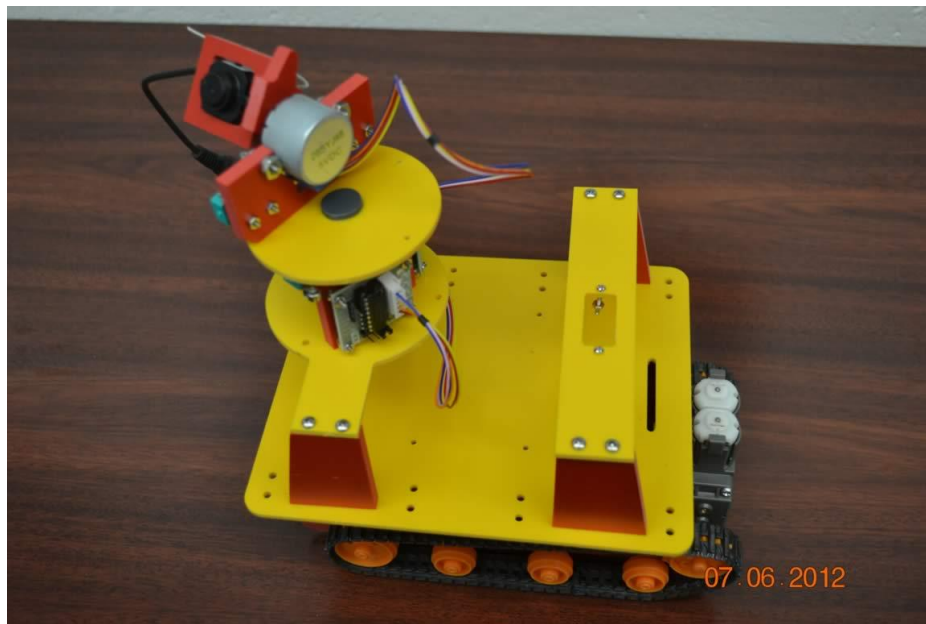


Figure 3. Basic Vehicle Platform

The Basic Platform

Using the autonomous vehicle as a point of reference, modifications were designed and developed by other faculty in the technology education program at the university. The model of the vehicle was constructed and tested in a very economic way. The current platform is constructed using Celtec^{®5}, which was purchased locally. It comes in 48" by 96" sheets in 1/8" and 1/4" sheet thicknesses. The sheets were cut into 24" by 24" sections and delivered to the community college for CNC machining. The drive train uses a TAMIYA[®] dual gearbox which comes with three volt motors. Through experimentation, these motors were replaced with six volt motors that provided additional power to the vehicle and worked well with the voltage supplied from the chosen Lithium-Ion battery.

Multiple copies of the basic vehicle framework were later manufactured at the community college. The vehicles were assembled at the university, and the vehicle and electronics were operationally tested and verified at another community college. Finally, the vehicles were used as part of a robotics course at a local high school.

Other Available Tools

The university has also developed the wireless controller and has developed options for the community college and public schools to add a wide range of options for their use with the vehicle. One option for the controller is a microcontroller development board previously developed at the university under the National Science Foundation grant. It uses a PIC Microcontroller from Microchip^{®6}, which also provides numerous tools for development of software to control the vehicle using Assembly, C, or BASIC languages. The PIC microcontroller Integrated Development Environment (IDE), MPLAB^{®7}, is provided free of charge. There are also third-party versions of BASIC, if that is the preferred programming language, and of various versions of C and Java-like programming applications; some are free or have low-cost for academic versions. When used on the development board, the PIC easily interfaces with the wireless communications via the MRF24J40MA module without additional components. As a development platform, the basic vehicle and microcontroller development board present numerous options for the controller of choice by the institution that adopts the platform. The Arduino module is another option that can also be used with this development board. For example, operation has been demonstrated using the Arduino open source application and using Bluetooth[®] for another optional wireless communication.

Advantages of Collaboration

Public schools, some with limited budgets, no longer need to search for a training platform that has a low cost and is easily adaptable to fit their curriculum needs; the autonomous vehicle can fill those needs. With this basic platform, the robotic vehicles can be developed in stages. First, it can be driven by an umbilical system, so students learn the basics of its motion and how it should be driven by the controller. Then, the platform can be adapted to the controller's electronics, expanding the system to include the line following, wireless-remote, and autonomous capabilities.

Instructors at all levels in the educational process are trying to inspire the next generation of engineers and technologists and may not have the time, or access to all of the tools, that would allow them to develop a similar training system by themselves. However, through the partnering with the other institutions, these tools become readily available. If fabrication facilities are available, projects can be produced by simply transferring computer files. Using Computer Aided Design and Computer Aided Manufacturing (CAD/CAM) files can be converted into instructions that operate automated machines. Construction of the vehicles is from a light-weight material easily machined using a Computer Numerical Control (CNC) router. These tools are commonly found at the community college in machinist or mechatronics programs. The ability to turn out all of the components rapidly and in mass quantities dramatically reduces the cost per platform. Being a member of a team with common educational goals and using available tools to achieve these goals creates a significant leverage for instruction and makes the task easier for every

Assessing the Effectiveness of the Collaborative Efforts

This collaborative effort between 2- and 4-year institutions and local high schools is in the early stages of development. The implementation of the common platform has just started with one high school teacher. Assessment data have not been collected to date. Plans are for comparisons to be made between class grades from the year prior to implementation of the autonomous vehicle into the curriculum and this year's student grades. Students are also required to complete certifications exams. The pass rates on certification exams between years will also be measured. These data are needed to validate the effectiveness of these collaborative efforts, especially student learning.

Summary

Preparing students to be successful in a career after graduation is the goal for high schools, community colleges, and universities. Faculty working at each level of education who are participating in this collaborative effort share this goal. This group has taken knowledge learned through research and experimentation and have moved it into different levels of instruction. With the basic training platform for the autonomous vehicle and the collaboration of the partners, the instruction of embedded system designs and robotics can go beyond what any one of the institutions could accomplish individually. The sharing of resources and opening the gateway that it creates makes this a project perfect for collaboration. More time and efforts are still needed to justify the effectiveness of this project beyond joint collaboration to improved student learning.

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