Wireless Mobile Robots: A Tool for Undergraduate Electrical Engineering Instruction

Project description

As a key element of its information technology vision, Montana State University (MSU) is embracing the use of mobile technology and has launched a campus-wide effort to deploy a wireless network to empower the Montana State University community with ubiquitous, convenient, and effective access to computing resources to further the instructional, research and public service mission of the university. Academic departments, such as Electrical and Computer Engineering (ECE), are examining ways of leveraging the wireless infrastructure to enhance classroom activities.

At nearly all of the nation's universities, freshmen engineering students are required to enroll in an introductory laboratory course. The manner in which the introductory material is presented can profoundly influence a student's enthusiasm and interest in subsequent course work and, ultimately, a successful professional career. Given the recognized need for continuous innovation in the freshman engineering curriculum, we chose to rejuvenate our basic first year introductory engineering course, EE101, utilizing student-constructed roving robots. Our intention is to actively engage promising young engineering students in the fields of electronics, robotics and embedded computer systems—areas of ever-increasing importance to this nation's goals in communications, transportation, and space exploration. Because each of our students will now have a mobile and programmable robot, we can capitalize on their experience by utilizing the robots as a teaching platform in subsequent courses. Specifically, we propose to incorporate wireless communication technology between the robots and laptop or tablet computers to support student learning in communications, embedded systems, and control.

The robot was developed by ECE under separate funding (NASA Space Grant Consortium funds) in 2004 and successfully introduced in EE101 in fall 2004. The course incorporates hands-on learning, teamwork, problem-solving skills, and an introduction to the analytical and design processes underlying modern engineering science. We also increased the academic credit to 2 credit hours and added a weekly lecture period to supplement the lab experience. The revised course was taught for the first time during the fall 2004 semester. The assessment results were excellent: 88% of the students reported that their interest and enthusiasm for electrical engineering was increased by the robot project, 89% reported that they gained practical and useful knowledge in the course, and more than half of the students felt that the course had given them more confidence in their ability to succeed in engineering.

This NWACC grant will be used to develop an 802.11 b/g wireless interface on the robot, install the complementary wireless infrastructure in our teaching labs, and modify the curriculum of our microcomputer software engineering course, EE371— Microprocessor Hardware and Software Systems— to incorporate robot-centered instruction. This will enable the students to program and control the mobile robot in real time over the wireless network and to measure outcomes in real time. These additions will be leveraged by other courses in communications and control systems in the future.

Our academic leadership effort is producing mechanical drawings, schematics, laboratory experiments, and supplementary materials sufficient to allow other universities to adapt the course to their own needs. Further details on the EE101 robot project including lab manuals, class assignments and assembly guides are posted on our Web site http://www.coe.montana.edu/ee/rmaher/ee101/ecebot/.

Our proposed revisions to the syllabus for EE371 will enable students to reuse their robots to learn embedded-processor programming techniques using the mobile robot as the pedagogical framework. The robot uses the Freescale (Motorola) HC12 microprocessor, which is also used in EE371, so the technology and the software development environment for the HC12 is already in place. We have done preliminary work on building a wireless link for the robot in two senior design projects conducted in 2004, and we have demonstrated that the robot can be modified to accommodate the new wireless interface (see http://www.coe.montana.edu/ee/rwolff/EE580/EE%25seniordesginF05_dsrc.html). Thus, our demonstrated experience with the custom robot, with microprocessor education, and with the necessary wireless components indicates a high degree of confidence in the success and sustainability of this project.

Future steps call for inclusion of the robot in control and communications courses, where the students will be able to learn the foundations of these disciplines by immediately applying theory acquired in the classroom to examples based on tasks carried out with the robot. The wireless network and robot will enhance the continuity among the core courses in our curriculum, providing the students with a highly integrated and well-coordinated learning experience.

A significant advantage of this project is that it involves required courses in our curriculum. This ensures that the existing procedures for continuous assessment, documentation, and performance improvement required by the Accreditation Board for Engineering and Technology will be used and fully supported by the department and the College of Engineering. The department's procedures for course assessment are based on evaluating specific outcomes that support the broader program objectives. Outcomes assessment includes traditional examinations, student questionnaires, student performance with oral and written communication, and peer review of course materials and grading policies.

In addition to the existing accreditation-related assessment procedures, we propose to use two special assessment measures. First, we plan to use a special questionnaire administered in the semester following a student's participation in the revised courses. The questionnaire will solicit feedback on how the new curriculum affects the level of preparation of students as they take subsequent courses, and measure the student's current level of motivation and enthusiasm. This information will be compared to that supplied by students who have not taken the revised courses in an attempt to draw conclusions about our progress toward the course goals. Second, we will involve a teaching and learning expert from our Engineering office (Carolyn Plumb) as an outside evaluator of our course goals and objectives. This will allow an objective, unbiased assessment of our methods and results.

Summary

Impact—Adding wireless control and feedback capability to student-built robots will immediately enhance two MSU ECE courses, one at the freshman level, and another for advanced students.

Innovation—While robots are not uncommon pedagogic tools in engineering curricula, robots with industry-standard WiFi wireless connections are. Use of 802.11 wireless control technology anticipates the deployment of ubiquitous, roaming-friendly wireless networks and thus lays the pedagogical groundwork for MSU to become a leader in teaching robotics and other aspects of engineering based on this technology.

Feasibility—Assessment of the current robot-based EE101 curriculum is very positive. The wireless technologies proposed for initial application are well-understood and highly available. The faculty who will develop the wireless network components of the technology have 40 years cumulative experience with wireless technologies and embedded processors.

Technology Transfer and Outreach—We have prepared high quality materials for our robot-based EE101 course and have posted to the Web for adoption by other universities. We will do the same with the wireless component materials.

Leverage—NASA Space Grant Consortium funds were used to develop earlier phases of this project. Departmental funds are available to develop course materials related to the wireless technologies this phase of the project will add to the curriculum. We will seek additional funds for the project from the university's Computer Fee Allocation Committee.

Outcomes Assessment—Questionnaire-based assessment will be added to the standard assessment techniques used by our department and college, including those of the Accreditation Board for Engineering and Technology.

Project Schedule:

Our plan to incorporate the wireless-enabled robot in EE371 includes several steps, some of which can be carried out in parallel. These are described briefly below.

1. May-August 2005: Install wireless interface on robot. We have already done preliminary work on this task, adding a point-to-point wireless link to the robot as a senior design project completed in fall 2004. We will build on these results to interface an 802.11b/g PCMCIA, compact flash, or USB wireless interface to the robot mother board. This will require redesign of the PC board and modest software development to the MC68H12 microcontroller. Our custom robot PC board was designed specifically to allow this sort of enhancement.
2. July-August 2005: Assemble additional robots for student use in EE371 trial. Students enrolling in EE371in fall 2005 will not have assembled their own robots in EE101, as they took the course before the curriculum was modified in 2004.
3. May – September 2005: Revise EE371 syllabus and lab exercises to include programming the robot. The robot will be used in exercises that teach digital I/O, interrupts and debugging.
4. July - August 2005: Post material on project Web site, using current EE101 Web site as a starting point.

5. August 2005: Install wireless network in student lab. Our network is already configured to accept wireless access points. We have conducted a site survey and located the best position for the access point.
6. September 2005: Install CodeWarrior software on the laptop PCs. We already have experience with this software and the necessary licenses. Our department IT system administrator will be responsible for software management.
7. September – December 2005: Trial use of robot and wireless network in EE371, fall 2005. Supply students with robots for lab use (see item 2 above).
8. January – April 2006: Evaluate outcomes and revise curriculum and robot design as needed, based on fall 2005 experience. Provide final report to NWACC.
9. September 2006: Make use of robot in EE371 fully operational, fall 2006. Students will have their own robots, since they will have taken EE101 with its new curriculum in fall 2004.

Budget:

Programming or technical support $ 0

Materials and supplies $ 500

Hardware & software $ 3500

Use of special instruments or media conversion: $ 0

Student assistance $ 3000

Faculty summer stipend $ 3000

Project related travel $ 0

Access to networked resources $ 0

Other planned expenditures $ 0

Please Describe:

Total (may not exceed $10,000) 10,000