2007

Robotics in Multidiscipline Multicultural Projects

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Abstract

The United States Military Academy at West Point seeks to maximize the number of students that have the opportunity to participate in multidisciplinary and multicultural learning experiences. Meeting this increasing requirement while faced with budgetary constraints requires a low-cost, innovative approach. Faculty in the Department of Electrical Engineering and Computer Science built on their success of using robotics in the classroom to integrate computer science, electrical engineering and information technology students on project teams. Each project used a standard kit of equipment to design, build and test a robot that could complete a specific task. These projects, conducted at three overseas locations in foreign languages with local faculty and students, were a tremendous success. In this paper, we describe our methodology for integrating multidisciplinary and multicultural project members on undergraduate project teams and exporting this type of experience to distant locations while minimizing costs. In addition to meaningful project work, the students were able to increase their language proficiency, regional expertise and cultural awareness in their host countries.

I. Introduction

The purpose of this paper is to describe a methodology in using robotics to overcome challenges and achieve success with multidiscipline and multicultural projects. Universities continue to grow their semester-abroad programs. The purpose of these programs is to provide an undergraduate student with memorable learning experiences that emphasize an application or research project in the student's area. In addition to demonstrating the rich potential of the particular field of study, these programs help foster greater cultural awareness between students of different ethnic, social and religious backgrounds. Many schools, the United States Military Academy (USMA) at West Point being a good example, are addressing this need through interdisciplinary research projects. Among others, Carnegie Mellon University has done extensive work towards integrating robotics into education. Their work in establishing educational programs in technologically underserved communities is particularly noteworthy.[1] Further, their TeRK (Telepresence Robot Kit) Program represents an effort to provide affordable and easy to use kits for educators and students alike.[2]

The Department of Electrical Engineering and Computer Science (EECS) at West Point offers majors in electrical and computer engineering, computer science and information technology. As such, its students have a broad range of interests and backgrounds. The challenge of presenting them with exciting and relevant educational events becomes an exercise in developing projects that match the interdisciplinary composition of the student teams. In particular, EECS projects seek to integrate electrical and computer engineering, computer science and information technology students that have completed their sophomore or junior year. These students have had a solid basic education in their fields. They are at the point of deciding which field of their discipline to specialize in and which electives they might be interested in taking. In addition to coursework towards their major, every student takes a core curriculum of 26 courses in a four year bachelor's degree program which includes math, science, humanities and social sciences.

EECS has answered these challenges and others by building from its successes in using robotics in the classroom. In the past four years, the EECS Department has seen a paradigm shift with an increased focus on robotics partly due to the wide-use of teleoperated platforms in Iraq, Afghanistan and elsewhere. Further, the Department of Defense has mandated that 30% of all ground vehicles be unmanned by the year 2015.[3] In response to these changes, the curriculum now includes a robotics thread sequence where students take courses in microcontrollers, mechatronics and control theory. Incoming sophomores are now given an iRobot® Create™ which they will use throughout their 3 years in the major. Computer Science majors regularly program in Java and C to develop sophisticated control algorithms and simulations for unmanned aerial and ground robotic agents. For information technology students, many core courses and electives involve laboratory exercises and projects using robots. EECS also offers a three course EE sequence to non-engineering majors. It is heavily integrated with the successful Parallax Boe-Bot® (Board of Education Robot). Student interest and involvement has seen a marked improvement with the greater emphasis on robotics in the classroom. Many other schools have seen the benefits of using robotics in the classroom as well.[4]

This paper illustrates how robotics brought together multidiscipline and multicultural project groups using a low cost and transportable educational platform using two case studies. Through using a small footprint board and chassis, our teams constructed robots to achieve specific objectives. They learned how to construct, program and troubleshoot a simple robot. The students also learned how to define and communicate design and performance parameters to people in other professions and other cultures. Lastly, our students greatly increased their language proficiency and regional awareness through a cultural immersion program in a short amount of time.

In our approach, we organize this paper as follows: Section II provides an overview of the academic individual advanced development program at West Point. Section III involves our project methodology. Sections IV and V describe two case studies that we conducted in France and Tunisia. Future work and conclusions are found in Sections VII and VIII respectively.

II. Overview of the Foreign AIAD Program

The mission of the Foreign Academic Individual Advanced Development (AIAD) Program is to coordinate international educational and cultural opportunities for cadets at West Point. These experiences typically occur during the spring semester for 7-10 days, over the summer break for 3-4 weeks or as a semester abroad. Cadets travel in small groups led by an officer in charge to study a wide variety of topics in countries all over the world. These projects are intended to enable the student to demonstrate the ability to conduct independent inquiry, as well as inspiring them to study topics that may become relevant as they undertake their senior capstone project.

In addition to the project work, the program provides resources to support the development of cadet regional expertise, foreign language proficiency and cultural awareness. Each cadet conducts an in-depth study of the host country and region prior to the trip. Staff rides, historical visits and cultural trips are all part of the experience. The historical significance of the country and certain sites are studied to culminate in a briefing at the actual location. Cadets enhance their verbal and written language skills through classroom instruction, online preparation and conversational exercises. Politics, religion and regional influence are all considered and studied. Every cadet becomes an expert on their host nation prior to their travel there.

In the summer of 2007, the Department of Electrical Engineering and Computer Science sponsored over 200 students on 74 separate AIAD projects. These projects were sponsored by a wide variety of government, industry and academic organizations. Each project was mentored by a faculty member, who was responsible for selecting the students. Discussions between EECS faculty, the students and the sponsors tuned the project to meet both the sponsors' and the students' goals. Of these 74 projects, four involved overseas sponsors. Teams of students went to England, France, Tunisia and Chile to work on engineering projects. The sponsors for the projects in France, Tunisia and Chile worked together to develop an interdisciplinary, portable project that would suit the skills and goals of cadets majoring in electrical engineering, computer science and information technology.

III. Project Methodology

Once the cadets were selected, the mentor considered their technical skill set and interests in developing the project. The planning and preparation for all three cultural experiences took more than one year. Initial coordination consisted of contacting the International Affairs office at the host universities as well as agreements between the Electrical Engineering and Computer Science Departments as to a mutual project. The project plan was similar for each team, varying only where constraints on material or personnel required. The team in Tunisia broke into three groups to build a leader robot, a follower robot and an autonomous robot. The group in France settled on a robot that would navigate a maze. The cadets in Chile worked on a robot that would map a room. In all cases, the same sensors, controller and chassis were used.

The general plan was for the teams to arrive at their AIAD location and construct a robotic system using the Parallax Boe-bot® (Figure 1). It was expected that the first week would involve designing the robot to achieve a specific goal. This first week's work would extend into the second week, as cadets programmed and wired the various sensors they had included in their designs. Testing and documenting their work would consume the third week, culminating in a project demonstration and oral presentation. Final presentations not only allowed the students to practice their foreign language skills but also their technical abilities.

Each cadet team was given at least one Boe-Bot®. The Boe-Bot® was chosen because of its low cost ($149) and small footprint (3½ pounds for a full kit).[5] The faculty mentors of the three teams agreed to use either the Javelin Stamp™ module or the BASIC Stamp® module. The Javelin Stamp™ is a microcontroller that is programmed using a Java compiler running on an Integrated Development Environment (IDE). The BASIC Stamp® is programmed with a PBASIC® editor. Both software packages were downloaded and installed at no cost. In addition to the robot chassis, printed circuit board and microcontroller, teams were issued a package of sensors that included ultrasonic rangefinders, tactile whiskers, photo-resistors, infrared (IR) transmitters and receivers, a liquid crystal display (LCD) and a digital compass. Each group chose one of various options, formulated an initial plan and timeline, required materials, division of labor (either hardware, software or management) and final end state. This phase ended in a project presentation detailing the group plans.

Figure 1: Boe-Bot®

The groups continued their research and searched for online information to include datasheets, sample code and sensor integration. At a minimum, each cadet had taken an introduction to information technology class using Java and a sophomore level digital logic course. This early experience in Java helped shape some of the decisions pertaining to the programming language used for the group projects. Cadets that had finished their junior year had completed courses such as computer architecture, circuits and data structures.

In addition to being small, transportable and an easy to use programming language, the BASIC Stamp® and Javelin Stamp™ modules and Boe-Bot® chassis were extremely affordable. Many of the foreign universities involved in these joint projects did not have the ability to purchase expensive robotic platforms and the accompanying software. Therefore, it was imperative to assemble a kit that was both affordable and transportable. The host universities all had computer laboratories with Internet connectivity. The free software packages were easily installed on the local machines without the need for licenses or additional systems.

By using a common programming language such as Java, the foreign students were already familiar with the software environment. The Boe-Bot® chassis has an extremely small form factor measuring 4 x 5 x 3 inches. With small dimensions, light weight and low cost, the Boe-Bot® is ideal for easy transport and setup. The reference manuals, instructions and online documentation allow the student to quickly build a working platform. At the end of the internship, one kit was donated to each host university to continue joint research and to have a common platform for development in future exchanges.

IV. A Case Study in France

The École des Mines (EdM) computer research facilities are located in Fontainebleau, France, approximately 60 km south of Paris. Established in 1969, it is primarily a graduate research institution and offers Master of Science and Doctoral degrees. The EdM faculty sponsors provided the cadets lab space and network support for the project.

One of the goals of the project was to introduce cadets to French culture and provide them the opportunity to expand their command of the French language. Because of the structure of the French education system, the French students were the same age as the cadets but had completed more classroom education. None of the French students had ever served in the military, so the exchange of cultures and views was bidirectional as they were as interested in life at the Academy as the cadets were envious of their civilian counterparts' open-ended schedules. The cadets that were selected to go to France all had classroom instruction in French, both at the high school and college levels. One of the cadets had been to Paris on a school trip years ago, but none of them had had the opportunity to experience living and working outside of tourist locations.

In addition to linguistic requirements, the cadets were selected because of their scholastic achievements in computer science and electrical engineering. While none of them had experience in robotics, the two computer science (CS) majors had completed courses in Java and the electrical engineering (EE) major had received high marks in his circuit design courses. Before leaving USMA, they were briefed on the project and given a chance to prepare using the Academy's research library. Time constraints prevented any chance for a hands-on familiarization with the robot, but they left for France confident that they could tackle the problem.

The team carried with it a standard robot kit, a sensor package, and a variety of basic electrical tools and supplies, such as extra wire and batteries. Using their school laptops, they installed the Java Integrated Development Environment and downloaded documentation and software from the Parallax site. After settling into the lab at EdM, the group proceeded to get organized. The group was tasked to create a robot that could negotiate a maze constructed of 90 degree turns. One cadet took the lead in locating source code for the sensors while the other two assembled the basic robot chassis. The team worked from 0800 to 1600, keeping the same hours as the French sponsors. Breakfast and lunch provided key opportunities for cultural interaction and linguistics. After discovering the EdM daily schedule, the cadets established a project schedule that would allow them to complete the project and see the sights.

Figure 2: Cadets at work in the lab

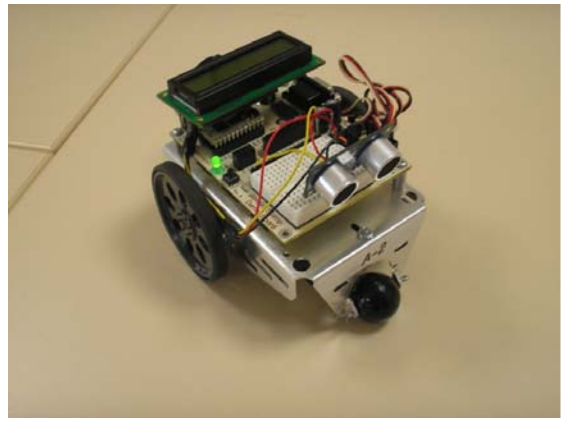

Figure 3: First robot prototype

After work, the emphasis in the first week was on discovering the nuances of daily life in France. Cadets were introduced to experiences such as driving to work, buying groceries, and ordering in a restaurant. As mundane as these tasks sound, they provided an interesting challenge to young people who had never been outside of the United States.

Their basic design mounted an ultrasonic range finder on the basic chassis to find an open path for the robot to travel. A liquid crystal display (LCD) panel was installed to help troubleshoot programming. By the end of the first week, however, the cadets had also rounded out their experience in robotics. A wiring change to the battery pack rendered the ultrasonic range finder inoperative, so they were forced to change their design to use infrared (IR) rangefinders and "whiskers" to detect the walls of the maze.

Since these cadets were more advanced in their field of study than those of the other two teams, they assumed the role of providing software and hardware advice and assistance. The computer science students took the Java packages from the Parallax site and refined them to work correctly. At the same time, the electrical engineer worked out a corrected set of pin-outs for each sensor. These were shared with the other teams through email.

After a weekend of sightseeing in Paris, the cadets jumped into the second week of project work. The team discovered that the whiskers were effective in locating the walls, but that the software procedure they were using to turn the wheel servos and maneuver the robot away from the wall was not as precise as the maze required. They added a compass sensor to the robot and revised the software to make more precise turns.

One unforeseen opportunity involved the cadets speaking at a French lycée (high school). They were able to visit an English class of French students. The second weekend was a French public holiday and the team journeyed to Normandy to see museums and locations associated with the D-Day invasions of 1944. The experience of navigating along European highways was a great learning point of the weekend. This opportunity took the cadets completely away from their English-speaking sponsors and exposed them to French views on Americans.

Figure 4: Visiting the Jardin du Luxembourg in Paris

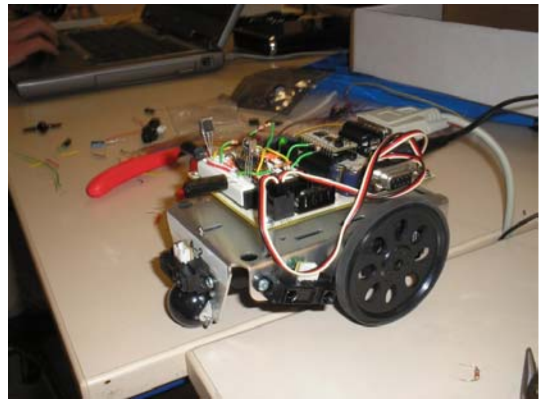

Figure 5: Second prototype robot with IR sensors

Upon returning to the lab, the cadets managed to locate another ultrasonic range finder and used it to replace the IR sensors that they had been unhappy with. They mounted the rangefinder on a mast and used a servo to turn the mast to find an open path, rather than turning the robot as they had done with the statically mounted rangefinder. During the third week, the cadets expanded their trial maze and ran the robot through more testing.

As the end of the trip drew near, one cadet was designated to prepare the project briefing while the other two made final refinements on the robot. This multimedia video highlighted their cultural experiences in addition to the features and successes with the robot. They delivered a presentation to the EdM faculty and students, struggling at times in French, but having the confidence to talk about their experiences to get their message across.

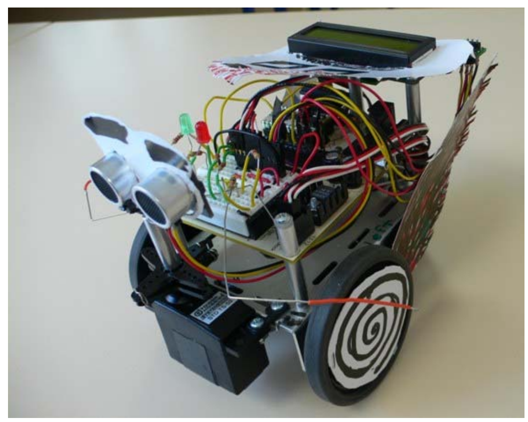

Figure 6: The Final Prototype. Note the rangefinder mounted on the rotating mast.

At the end of the three week experience, they all agreed that the Boe-Bot® Javelin Stamp™ was well suited for introducing robotics to students who had a basic understanding of Java and circuits. While they had rewritten most of the example code from the Parallax site, the immediate feedback provided by the robot's performance kept the cadets very engaged in their project. They discussed ways to expand their opportunities to interact with French students, and these are being considered in light of logistical and financial constraints.

V. A Case Study in Tunisia

The Université Libre de Tunis is a private university created in 1973. It offers bachelor and master degrees in engineering, science and technology, humanities, business, language and culture studies. The laboratory facilities, workshops and computer rooms are configured for Internet access to provide the students with a modern means to learn and conduct research.

During this joint project, there were a total of twelve Tunisian students from a variety of countries to include Algeria, Libya, Nigeria and Cameroon speaking English, French and Arabic. The academic language is French and was spoken and written by all of the students. The Tunisian students were from a myriad of backgrounds and education levels – electrical engineering, computer science, mechanical engineering, undergraduates, graduate students and working with industry students. Almost all of them were at the graduate level and had experience in both computer hardware and software. Prior to our joint project, the university did not have any robotic platforms for their courses or to conduct research. It was truly a multidiscipline, multicultural group.

The four cadets participating in the Tunisian AIAD were from four different majors: electrical engineering (EE), computer science (CS), information technology (IT) and engineering management (EM) and all had just completed their sophomore year. Due to large number of core courses at West Point in math, science, English and other humanities, the four group members had limited technical engineering experience. Compared to their Tunisian counterparts, the cadets had completed only two courses (introduction to information technology and digital logic) that were directly related to programming and developing robotic systems.

All of the cadets had taken at a minimum four years of classroom instruction and all had spent time in a French-speaking country. Working with the Department of Foreign Languages also assisted the cadets in their preparation for language immersion – either through online or one-on-one instruction. Prior to the trip, each cadet conducted an in-depth study of Tunisia and the surrounding region. The cultural and historical areas were divided into four topics: Roman influence, Islamic culture, medieval history and military campaigns in North Africa. Each cadet prepared and conducted cultural briefings before the trip began and they also coordinated with the Department of History to gain valuable insight into their assigned area.

The cultural trips during the three week period proved to be immensely rewarding. The cadets visited the historical city of Carthage, toured ancient Berber villages, walked in the Sahara desert and learned about medinas, Islam and mosques. The cultural research paid off as cadets briefed about their particular area while standing on the actual site. Further cultural awareness and regional expertise was gained from the daily interaction with the Tunisian students. The cadets were invited into their homes, participated in sporting events like soccer and shared many stories and ideas to enhance understanding on both sides. Difficult topics like politics and religion were not avoided: Israel and Palestine, Iraq and Afghanistan and how Muslim countries look at the West. To be accepted for the program, each cadet had to possess a baseline level in spoken and written French.

Figure 7: Visiting Carthage

The project lasted for three weeks with five working days per week. Groups would begin at 0800 each morning, break for lunch and then conclude at approximately 1700. Some groups stayed later depending on their schedules. The first week primarily consisted of introductions and forming project groups. The students were separated into three groups based on disciplines. Three project proposals were presented: a leader robot, a follower robot and an autonomous robot. The emphasis for the first few days was on verbal and written communication skills (in French). Not being their primary language, the cadets struggled initially with speaking and simply learning nonverbal cues. Frustration could be seen on both sides but by the end of the first week, the groups had begun to effectively work together. There were two briefings during the initial week to convey project goals to all the faculty and students involved.

Figure 8: Project teams in the classroom

With the start of the second week, the project groups began their hardware and software development. For hardware, each group was given a Parallax Boe-Bot® robot and could choose between the BASIC Stamp® or the Javelin Stamp™ module. A wide range of sensors and I/O devices were available to include LEDs, infrared transmitters and receivers, ultrasonic sensors, touch sensors, liquid crystal displays, accelerometers and digital compasses. The Boe-Bot® contains a breadboard, plenty of headers and is powered with 4 AA batteries. From simple line-following projects to complex mapping and localization, the Boe-Bot® has a wide range of functions that can easily be ported to a foreign country at a small cost. On the software side, the cadets had the option to use the BASIC Stamp® Editor to program in PBASIC or the Javelin Stamp™ Integrated Development Environment using Java. One of the key benefits of the development environment was instant feedback. The teams could quickly compile and download their code to immediately test an LED, servo, LCD display or any of the I/Os they were using.

Figure 9: Leader-follower test track

The students formed three groups that were balanced based on expertise and backgrounds. The first team aptly called themselves Le Meilleur (The Best) Group and chose to implement a line-following leader robot. This project did exactly as its name suggests, followed a ¾ inch strip of black electrical tape. The students started with a pair of IR transmitters and receivers provided in the sensor sampler kit. They quickly developed their project into a working system and built a track in the laboratory for testing. Further, they implemented the IR transmitter for the follower robot along with their line-following functionality. The follower robot group built an IR receiver onto their platform to detect and follow a signal from the leader robot. The two groups were able to successfully test and run their robots on the track.

The third group implemented an autonomous robot to navigate around walls and obstacles in a room. Their first task was to integrate the ultrasonic sensor to measure the robot's distance to obstacles. Upon successful testing, they added an LCD display which provided a regularly updated readout of distance in inches. They used pre-written software functions for both the ultrasonic sensor and the LCD display. These functions were provided by the French AIAD group who were working on the same problem. This collaboration assisted both groups with the open sharing of ideas, problems and solutions. The members then used a radio controller to move the robot around obstacles and to test the LCD as it displayed distance. During the third and final week, each group presented their work in a 30 minute presentation to the faculty and students. Their technical speaking and oral and written communication skills improved significantly in a short amount of time.

The joint project work proved to be extremely rewarding for everyone involved. The Tunisian students and cadets successfully designed and built small robotic systems to accomplish their assigned tasks. In addition to the educational benefit, the diversity among the teams and the multicultural immersion proved to be even more valuable. All of the students achieved a greater understanding and respect for one another and their culture.

Figure 10: Faculty and Students

VI. Future Work

USMA will continue the AIAD program through 2008. Plans are underway to send cadet project teams to the same institutions as in 2007. There are also preliminary discussions that could result in AIAD teams working with universities in Honduras and Santo Domingo. In addition to sending cadets to foreign countries, the intention is to have students from France, Tunisia and Chile travel to West Point for an exchange here in the United States.

Further, USMA faculty seek to continue its collaboration and research to provide even better opportunities for cadets and those students from the host countries. This work will enable longer cultural and academic exchanges to span over an entire semester. By providing this foundation now, USMA faculty desire to build a program that will remain for years to come.

VII. Summary and Conclusions

This paper has described a methodology used by EECS to integrate multidisciplinary and multicultural project members on undergraduate project teams using robotics. Illustrated by two case studies, this approach facilitated a low cost, easily exported platform that allowed undergraduate students to expand their academic and personal experiences through a robotics project.

These experiences have led the EECS faculty to conclude that an expandable robotics platform like the Boe-Bot® can be programmed through a commonly used language like Java to form the basis of undergraduate research exercises. The immediate feedback offered by programming and observing the robot spurred students to find innovative and collaborative solutions to standard engineering problems. The confidence offered by the project also helped students overcome linguistic and cultural obstacles, enabling cadets to learn about other cultures as well as robotics.

The views expressed are those of the authors and do not reflect the official policy or position of the U.S. Military Academy, the U.S. Department of the Army, the U.S. Department of Defense or the United States Government.

VIII. References

[1] M.B. Dias, B. Browning, G.A. Mills-Tettey, N. Amanquah, and N. El-Moughny, "Undergraduate Robotics Education in Technologically Underserved Communities," *2007 IEEE International Conference on Robotics and Automation*, April, 2007, pp. 1387-1392.
[2] Telepresense Robot Kit: http://www.terk.ri.cmu.edu/
[3] Future Combat Systems: http://www.army.mil/fcs/
[4] Druin, A. and Hendler, J. "Robots for kids: exploring new technologies for learning," The Morgan Kaufmann Series in Interactive Technologies, Morgan Kaufmann, 2000.
[5] Parallax: www.parallax.com

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