Eclectic robotics for a mixed audience

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A course in robotics is being piloted this semester at Purchase College/State University of New York. It was designed for its particular audience: upper-level students in the mathematics/computer science major and in the new media major as well as any other student who have satisfied the programming pre-requisite, possibly through general education courses. However, the general ideas motivating the topics and structure may be of interest to the wider community of educators.

Among the majors offered at Purchase College are a combined mathematics/computer science major and a new media major. Major requirements are in addition to requirements in general education for all students. All students must satisfy what is termed the mathematics proficiency which is defined as being ready to take Pre-Calculus. Students also must satisfy a mathematics/quantitative reasoning general education course. *Computer Science I* and *Programming Games* (described below) are courses satisfying this requirement.

To earn a degree majoring in mathematics/computer science, all students take basic courses in mathematics (*Calculus I, II and III*, and *Linear Algebra*) and computer science (*Computer Science I and II*), make choices (*Advanced Topics in Mathematics* vs. *Data Structures*; *Differential Equations* vs. *Discrete Mathematics*); and pick 3 upper-level electives (for example, *Graph Theory*, *Number Theory*, *Networking and Security*, *Creating Databases for Web Applications*, *Creating User Interfaces*, *Emerging Web*). Credit for upper-level electives also can be earned by independent studies (for example, one was given recently in *Computability*), by grading, by being a lab assistant in the computer courses, and by participating in what is called informally 'server club', where students work as assistants to the computer technicians maintaining the servers, networking and faculty computers. While most students identify themselves and can be identified as taking the mathematics or the computer science track, some do take a mixture of courses. All students are required to participate in a senior seminar for two semesters and all complete a senior project under the guidance of a faculty mentor and spread out over two semesters. Students are encouraged to participate in the School of Natural and Social Sciences Student Symposium.

The New Media major is interdisciplinary in course requirements and program administration, involving faculty members in both the arts conservatories and the liberal arts schools of the College. Students are required to take a programming course (either *Computer Science I*, a standard version of this course, focusing on Java programming, or *Programming Games*, focusing on JavaScript and (Flash) ActionScript). Other requirements include *Creating Web Documents* (a mostly technical course focusing on HTML and CSS), *Digital Media Studio* (a more artistic oriented course, including the use of tools such as Photo Shop), *Basic Visual Literacy*, *Photography*, *Studio Composition* (focusing on creating audio productions), *Computers and Culture*, and *Shooting and Editing Digital Video* all in the first two years. In the middle of the second semester of the second year, students prepare a web-based portfolio (video can be presently separately), that presents work and includes essays on what they have done and what they want to do in the rest of the program. Students who are accepted for advanced standing on the basis of the portfolio and adequate grades have requirements to take courses in certain categories, participate in a junior and senior seminar, and choose electives from a list. This list includes the computing upper-level electives offered to the mathematics/computer science students and advanced courses in the School of Art and Design, the Conservatory of Music, the Conservatory of Theatre Arts and Film, and the sociology/anthropology program. As is the case for mathematics/computer science and most majors at Purchase College, new media students produce a senior project under the guidance of a faculty mentor and spread out over two semesters. Students are encouraged to participate in a New Media Senior Student Show.

The Robotics course is planned as an acceptable upper-level elective for students in either the mathematics/computer science or the new media program. The pre-requisite is at least one programming course so all students in both program can satisfy the pre-requisite. It is anticipated that students outside these two programs who may have taken a programming course to satisfy the mathematics/quantitative reasoning general elective may seek to enroll in the course.

The catalog copy for the new course has the following description:

> In this upper-level elective, students will be introduced to concepts and technologies for applications in the physical world in which motors, actuators and sensors are critical devices and real-world variability has significance that is not present in the virtual world of data manipulation. The lecture component of the course will include, as time permits, topics in industrial and healthcare robotics, autonomous vehicles, spying and identification systems, interactive art installations, and ethical issues. Students will be required to do research and prepare oral presentations and written reports on an approved topic of their choice as well as participate in on-line discussion. The lab component will focus on building and operating small, indoor, autonomous vehicles using Lego Mindstorms NXT kits. Students will work in teams in the lab on assigned projects and then projects of their own design from a wide variety of choices, including robot sumo or art installations. **Pre-requisite**: a programming course.

The grade allocation for the course is

Basic Lego Mindstorms projects	20
Midterm Quiz	10
Lego Mindstorms project of your own design (including documentation & presentation)	25
Research project on a robotics topic: paper and presentation	20
Postings (min. 2) and reply postings (min. 4) on robot related topics	10
Final quiz	15

The course, as suggested by this official description, has three attributes:

- Students will spend time working with the NXT kits. It is not the whole course, but a substantial part.
- The lecture content of the course will feature what could be viewed as more serious robotics, for example, robots in manufacturing.
- Students will take on some of the responsibility for their own and their peers' education through making their own choices for the research topic and the Mindstorms project and in the oral presentations and the on-line discussions.

The lab activity with the NXT kits is integrated, for the most part, with the lecture material on robots in manufacturing, health care and space. The tentative sequence of class topics follows (this is a 14 week term, including time for a midterm, but not the final examination):

1. Introduction to subject and course. What is a robot? 3 programming methods for robots: tele-operator, teach/playback, programmed. Shoe-tying (including first step). Automation: 'hard' automation, customization, system versus operation automation. Review requirements (lab projects, research project, postings).
2. (Lab) first project. Create iconic program: sound, forward, sound. Build
3. General and Lego: Motors. Actuators. Sensors. Strain gauges. Proximity. Units. Tolerance. Basic physics. Event driven programming.
4. (Lab) Add touch sensor to robot and to program.
5. Continue with sensors. Switches. Miniaturization. Fabrication vs. assembly.
6. (Lab) Add light sensor to robot and program. Calibration.
7. Washing machine example. Exercise to identify similar examples. General issue of 'anthropomorphic fallacy'. Very brief over of AI (chess history, Sudoku). Illusions of intelligence.
8. (Lab) Add ultrasonic sensor (proximity) to robot and program. Build new robot?
9. Coordinate systems. Articulated joints. Kinematics and inverse kinematics. Examples in industry.
10. (Lab) robo-sumo: finding and pushing other robot. Vulnerabilities.
11. Painting cars. Reasons for its prevalence. Issue of orientation/placement of parts. Vibrating table/channels for orientation. Remove need for orientation. Build-to-order vs. build-to-stock.

12. (Lab) Technology in search of problem: sound sensor. Brainstorm for game with Legos and brainstorm for 'real-life' examples.
13. Brief survey (topics appropriate for research project): Mars rover, walking robot, autonomous vehicle, vacuuming machines, home health workers, mail delivery in buildings, soccer, prosthetics.
14. (Lab) Bluetooth: messages between robots (and to home computer?). Brainstorm for game with multiple NXTs.
15. Brief survey (topics appropriate for research project or lab project): interactive art installation: sensing presence and changing displays. Randomness. (Start research projects)
16. MIDTERM
17. Brief overview: 3D CAD. Google SketchUp. Robo-doc medical project (criticality of use of CAT scan data).
18. (Lab) System for documenting construction of Lego robots. (Lego Digital Designer-if this system has Mindstorms bricks)
19. Current efforts: robot/human interface. Home cleaners. Home health care. Globalization. Transport of bits versus atoms. Economic issues relating to manufacturing.
20. (Lab) Continue work on class choice for networking robots.
21. AI topics: problems with anthropomorphic approach (washing machines, chess history). Back tracking. Heuristics. Sudoku example.
22. (Lab) work on Lego projects.
23. Library research presentations.
24. (Lab) work on Lego projects.
25. Presentations, as required. Follow-up lectures on topics.
26. (Lab) work on Lego projects
27. Review for final
28. (Lab) present Lego projects (including documentation)

Questions that are asked by colleagues (though not necessarily by those attending this conference) is whether or not this course is deserving of a place in the curriculum of a mathematics/computer science major or a new media major, given that so much else needs to be squeezed in. Is the course serious enough? Is it just playing with toys? The first author has experienced such questions when asked about the Programming Games course. That course is not playing games but building games. The fact is that constructing computers games is challenging, more challenging than most students expect. The challenges come from the criticality of designing and preparing the human-computer interface, representing the state of the game, and formulating the event handling. Similarly, building a robot, even following the directions in a kit and programming the robot to perform specific tasks requires considerable attention to detail and understanding of conditions such as real-world variability. Students must adopt disciplined ways of working with the equipment and define repeatable procedures for testing. Going beyond defined tasks to designing and then implementing their own projects requires creativity and programming skill. The performance of the robot projects are on view for all to see. The nature of robotics, the fun and the visibility, together with the unexpected difficulty, motivates and facilities deep learning.

The robotics course is appropriate as a topic for the mathematics/computer science majors. After all, automation involving sensors and actuators is as significant in the modern world as [data] automation in banking. Similarly, many new media students have indicated a desire to build interactive art installations and doing the robotics projects should supply ideas and provide understanding of how sensors and actuators can work.

More generally, the Purchase College students are not engineering students. They tend to be graduates of general high schools without any vocational training. Most appear to have very little understanding of how goods are manufactured. Though many have worked in service jobs, they have not done any deep thinking about the operations in these industries. These are deficits that should be addressed.

The robotics work can be presented to and appreciated by a wide audience. Though it is not our goal to participate in contests in the first offering, we may offer extra credit for attending and reporting on such events. This exhibitory nature of robotics provides opportunities to the mathematics/computer science majors generally reserved for the students in the Purchase arts conservatories.

Purchase College is a small institution and courses that serve multiple audiences have advantages. In this case, it is anticipated that students will come to the class with different capabilities. There will be programmers, builders, designers, planners, testers, and crew leaders. This is a good thing, not a bad thing. The students will benefit from working in teams and, hopefully, by trying something that they had not tackled previously.

These are the plans for the course. At the conference in March, we will report on the reactions and achievements of the students in the first part of the pilot class by sharing the results of a start of class survey and showing early work.