Wellesley College CS116/PHYS116
Robotic Design Studio
A First Year Seminar
Fall, 2010

Course Information

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Location: *Engineering Studio*, SCI L024. (Phone in SCI L024: 781-283-3346.)

Meeting Times: Tuesdays and Fridays, 1:30 – 4:00 pm

In today's world we constantly interact with a vast array of often intimidating and mysterious technological objects. In ***Robotic Design Studio*** you will become a designer and creator of technology, rather than just a passive consumer. And much of the intimidation and mystery will vanish.

This first-year seminar will introduce you to the essence of engineering by designing and assembling robots out of LEGO® parts, sensors, motors, craft materials and tiny computers. Working in small teams, students design and build their own robots for display at a campus-wide robot exhibition. These projects tie together aspects of a surprisingly wide range of disciplines, including computer science, physics, engineering, and art. **Open only to First Year Students. No prerequisites.**

The *Engineering Studio* (SCI L024) will be accessible around the clock, and I encourage you to tinker there outside the "official" hours of the class.

All students in the class are expected to participate in the Robot Exhibition from 4:30 – 6pm on Tuesday. Dec. 7. It is also absolutely necessary for you to participate in the cleanup party that will be held during the last class meeting on Friday, Dec 10.

Course Web Site: There is a web site with information pertaining specifically to this course at:

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http://cs.wellesley.edu/~rds/
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Course Overview

In this intensive introductory course, you will have an opportunity to design and assemble robots out of LEGO parts, sensors, motors, and miniature computers (PicoCrickets, and also "RDS Crickets", specially built for this course), and then program your creations to do your bidding. We start by learning some fundamental robotics skills in the context of playing with PicoCrickets and studying/modifying a simple robot known as SciBorg. Then, working in small teams, you will design and build your own robot. The course culminates in a Robot Exhibition on Tuesday, December 7, from 4:30 – 6pm, in which you will show off your robots to the Wellesley community. This is a festive event that is attended by students, faculty, staff, and their families, including many young children.

This course is rooted in *constructionism*, whose main tenet is that people learn best when actively engaged in hands-on projects that are personally meaningful and enjoyable.

Robotic projects tie together aspects of a surprisingly wide range of disciplines, including computer science, physics, math, biology, psychology, engineering, and art. Here are some of the concepts and skills you can expect to learn in this course:

- robot = sensors + controller + actuators.

- simple programming: robot commands, control flow (sequencing, conditionals, loops, procedure calls, concurrency), procedural abstraction.

- basic electronics: voltage, current, power, motors, sensors.

- fundamental mechanics: building robust structures, friction, power transmission, gearing, LEGO design clichés.

- animal and machine behavior, with ties to biological, cognitive, and social science.

You will also get hands-on exposure to some of the "big ideas" of engineering:

- hypothesis testing and debugging.

- making iterative improvements.

- working with *systems* (design in multiple domains, subpart interaction).

- designing *behaviors* (sophisticated behaviors can arise from relatively simple rules).

- working in the real (noisy, messy, unpredictable *etc*.) world.

- divide-and-conquer strategies for problem solving.

- modularity and abstraction.

- feedback and control.

- paying attention to *aesthetics*.

- the value of simplicity and robustness.

We believe that this kind of exposure to the important ideas of engineering should be a critical part of today's liberal arts education. A grounding in these ideas is necessary in order to understand our times and our culture. The best way to become fluent with these ideas is to become a designer and a builder. In today's liberal arts curriculum there is a relative absence of design and building for students of science or technology. In contrast, there tend to be lots of design experiences for artists and humanities students.

Prerequisites

The only prerequisite for this course is a willingness to learn about, and have fun with, robots. The course is not just for scientists – all creative people are encouraged to participate!

Credit

One (1.0) units of credit will be awarded for successful completion of this course. This credit counts toward the Natural and Physical Sciences (NPS) distribution.,

Robotic Design Studio does **not** count as a laboratory course.

Reading Materials

I will post several articles, manuals, and notes during the course, and will post suggested reading where appropriate. All handouts will be made available from the course web page.

Challenges

For the first 7 weeks of the course the class assignments will consist of a series of "challenges":

- Challenge 1; Kinetic Sculpture .

- Challenge 2; Simple Sciborg Behaviors .

- Challenge 3; Sciborg Line Follower .

- Challenge 4; Simple Line Follower Modifications .

- Challenge 5; More Sciborg Behaviors (Light Follower and Sobiety Test) .

- Challenge 6; Sensor Interactions .

- Challenge 7; Motion Modules .

- Challenge 8; Indestructible Box .

- Challenge 9; Single Motor Racing Vehicle .

- Challenge 10; Build Your Own Sensor .

- Challenge 11; Personal Fabrication .

- Challenge 12; Everyday Sensors .

- Challenge 13; Auto-Thresholding .

(All of the above challenges are collected in the following document: RDS Challenges.)

Homework

In addition to working on design challenges and other hands-on activities in during class time, you will be asked to complete several challenge problems as homework

assignments. Assignments will typically involve reflecting and expanding on work done in class, thinking about points raised in reading, or documenting stages in the design and construction of your robot.

Individual Design Blog

Each student is required to maintain an individual design blog to document her journey through the course. The design journal is a single artifact that should contain all of the following:

- answers to homework assignments.

- documentation of your solutions to the design challenges, including sketches, code, and explanation of strategies.

- documentation detailing the design and construction of your final project, including words, sketches, and code.

- other thoughts/observations/sketches inspired by the hands-on activities, reading, *etc*.

Design Blogs

Each student is required to maintain an individual blog to document her journey through the course. An individual blog should contain the following:

- documentation of your work on challenges and the final project, including text, drawings, code, images, and videos.

- other thoughts/observations/sketches inspired by the hands-on activities, reading, etc.

We encourage you to use a blogging application such as Blogger or WordPress to create and maintain your blog. I will examine your blog regularly throughout the course to check your progress and to provide feedback on your designs, and insights. At the end of the course we will examine your individual documentation of the final project.

Collaboration Policy

You will work on projects in pairs. You are strongly encouraged to change partners periodically during the semester.

Although you are working with a partner it is essential that you each maintain your own design blog. There will be certain deliverables for each project that can be submitted jointly and others that need to be submitted individually. Details will be specified with each project assignment.

You should use your design blog as a kind of diary in which you write down/sketch all thoughts, designs, etc. you have that are relevant to the robot course. If you have an idea, don't wait until later to jot it down; jot something down right away and then maybe flesh it out more later.

I will examine your design blogs at regular intervals throughout the course to check off your progress on challenges and to provide feedback on your robot designs. At the end of the course, your design blog should contain a detailed description of the process by which your final project took shape. The write-up of your final project design in your blog should be something that has evolved on a day-to-day basis, and not something you compose in a mad dash at the end of the course!

Group Robot Project

The second half of the course is devoted to the robot project, in which you will work in a team of two or three to design, build, exhibit, and document a robot. The project is open-ended; you should brainstorm with your partner about projects that are fun, exciting, and challenging, but at the same time realistic. To give you a sense of what's possible, you should browse the web pages describing projects from previous incarnations of the course (1996 – 2009). These are accessible from:

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http://cs.wellesley.edu/~rds/museum.html
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When forming teams for your project, it is wise to choose teammates with complementary strengths. For example, it's good to have members with programming experience, mechanical know-how, artistic sense, and good writing and presentation skills.

As part of your robot project, you will be expected to do the following:

As a group:

- *Develop* a preliminary design for your robot, including sketches, descriptions of behavior, and perhaps some high-level pseudo-code. All groups will give a brief presentation of their robot designs in class on Tue., Jan 16. As part of the presentation, you should write up and distribute a

preliminary design document to the class.

- *Build* the robot you have designed. This is an iterative process in which you will build, program, test, see what works and what doesn't, and make changes to the design. You repeat this process until you are done (rare) or you run out of time (more likely).

- *Exhibit* the robot you have built at the Robot Exhibition on December 7, 2010.

As an individual:

- *Document* the design and implementation of the robot in your design blog. In particular you should try to highlight the contributions you individually made to the project.

Grades

Rather than focusing on a grade, we hope that you will focus on learning a lot and having fun while building creative robots. After all, students during two previous Wintersessions ('96 and '97) built *very* impressive projects without receiving any credit at all!

Your grade for the course will be determined by three factors:

1. Your design blog, which includes your homework assignments and your individual documentation for your group final project.

2. Your group robot project, including the web page documenting your group's robot.

3. Your class preparedness and participation. It is expected that you will attend all classes.

In keeping with the College's grading policy, I expect that the average grade in this course will be no higher than a B+.

I hope that the grades will not stifle your creativity or otherwise detract from your experience in this course. If you think they might, I suggest you consider taking this course on a credit/non-credit basis.

Collaboration Policy

We strongly encourage you to get to know all of your classmates and to collaborate

extensively with them. Because of the interdisciplinary nature of the course, it is likely that you will be strong in some areas but weak in others. Please share your strengths with others, and don't hesitate to ask others for help in the areas in which you feel that you are weak.

In your design journal, all observations, reflections, and documentation should be in your own words. You may reference the ideas of your classmates, but should give them proper attribution in your writing.

Laboratory and Computing Environment

Classes will be held in Science Center room L024. This room will be referred to as the "Engineering Studio". The room will be unlocked during the normal weekday hours of the Science Center. However, you will have access to the room 24 hours a day, 7 days a week during the semester; details will be announced in class. Science Center policy requires that every student have a "buddy" when working after hours.

The lab is equipped with 10 iMac computers. We will primarily use the following applications during the course:

- *PicoBlocks* and *RDS PicoBlocks* : program development environments for the *PicoCrickets* and *RDS Crickets*.

- *Scratch*: another "block-based" programming language, similar in spirit to *PicoBlocks*, developed by the *Lifelong Kindergarten Group* at the MIT Media Lab.

We also encourage you to document your robot's progress by recording video clips.

Each student should back up her daily work onto memory sticks and/or their FirstClass accounts.

FirstClass Conference

The `CS/PHYS116-F10` FirstClass conference is a place for members of the class to communicate with each other.

Course Schedule

There are twenty six 2.5-hour class meetings, which naturally split into two categories:

1. During the first 13 or so class meetings, we will teach you the basics of robot design. These meetings will consist of lectures interleaved with numerous hands-on activities in which you will modify an existing robot or build a simple robot from scratch.

2. During the last 13 class meetings, you will work with your partner on the design and implementation of a robot for your final project.

Below is a tentative schedule for the class:

Week 1 *Introduction to Robot Design: PicoCrickets*

- What is a robot? Sensors, actuators, and controllers.

- Introduction to the *PicoCricket*, a tiny robot controller.

- *PicoCricket* examples: *Happy Birthday, Movers and Shakers, My Pet Duck Dancing Crickets*, *Thermostat*, *Pickle-lo*.

- Introduction to *PicoBlocks*, a graphical programming language for the *PicoCricket*. actuator & sensor primitives; control flow (sequencing, conditionals, loops); procedural abstraction.

- Course administrivia.

- Level-triggered vs. edge-triggered events, variables, simple multitasking.

- *Challenge 1:* Build your own kinetic sculpture.

- The *PicoBlocks* text language.

- Kinetic sculpture show-and-tell.

Week 2 (Sept. 14 and 17) *More Robot Programming; RDS Crickets and SciBorg*

- Introduction to the *RDS Cricket*

- Introduction to *SciBorg*, a pedagogical robot.

- *Challenge 2:* How does *SciBorg* follow a line?

- Study *SciBorg* line-following code.

- *Challenge 3:* Simple *SciBorg* modifications (Homework).

- *Challenge 4:* Modify the *SciBorg* to do the following (Homework):

   1) **escape:** use front bump sensor to escape from barricaded surroundings.

   2) **going the distance** – use shaft encoders to drive a specified distance, regardless of terrain

   3) **sobriety-test** - improve *SciBorg* line-following behavior by minimizing constant weaving on relatively straight portions of track. Also, try using shaft encoders to drive straight

   4) **light follower** - get *SciBorg* to "home in" on a light source.

- *Challenge 6:* Sensor interaction (Homework).

Week 3 (Sept. 21 and 24) LEGO Structures and Mechanisms

- Overview of LEGO Technic components.

- Idioms for robust LEGO construction.

- *Challenge 7:* Pick one of the *PicoCricket* "motion modules" and build it by following the instructions.

- *Challenge 8:* Build an "indestructible" LEGO box that can survive a 2 meter fall.

Week 4 (Sept. 28 and Oct. 1) *Iterative Design*

- Power transmission: motors, gear trains, speed vs. torque trade-off, friction, worm gears, bevel gears, differential gears, chains and treads.

- *Challenge 9:* Build a single-motor racing vehicle. The vehicle will participate in a 3 meter race carrying the *PicoCricket* and a 1.0 kg mass.

- Testing and improving your racing vehicle designs

- Vehicle races.

Weeks 5 and 6 (Oct. 5, 8 and 15) *Sensors*

- Sensors: Analog vs. digital sensors. How to build your own sensors.

- *Challenge 10: Build Your Own Sensor*.

- *Challenge 13:* auto-thresholding (Homework).

- Introduction to the *Scratch*

- The *Scratch Sensor Board (Pico Board)*

- *Challenge 12:* build your own *Scratch* sensor

Week 7 (Oct. 19 and 22) *Rapid Prototyping, Final Project Brainstorm*

- Rapid prototyping demos: laser cutters and 3D printers.

- *Challenge 13:* use the laser cutter or 3D printer to build a simple part

- Robot project brainstorming.

- Show and tell: robots from previous years.

- Video festival: *Robo-Pong*, *The Way Things Go,* and more!

Weeks 8 – 14 Final Project

Week 8 - (Oct. 26 and 29) Preliminary Sketches

- Pick teammates for final project.

- Begin work on preliminary robot project design: descriptions of behavior, sketches.

Week 9 – (Nov 2 and 5) Preliminary Design Presentation

- Continue work on preliminary robot project design: descriptions of behavior, sketches.

- Present preliminary design to class for feedback.

- Begin implementation of robot projects.

Week 10 (Nov 9 and 12) - *Robot Implementation*

- Groups continue to implement and document robots.

- **Groups present current state of robots to get feedback.**

Week 11 (Nov. 16 and 19) - *Robot Implementation*

- Groups continue to implement and document robots.

- **Groups present current state of robots to get feedback.**

Week 12 (Nov. 23) - *Robot Implementation*

- Groups continue to implement and document robots.

- **Groups present current state of robots to get feedback.**

Week 13 (Nov. 30 and Dec 3) In-Class Exhibit and Filming

- Robot implementation and documentation continues.

- **In-class demonstration of your robots for evaluation and filming.**

Week 14 (Dec. 7 and 10) *Robot Exhibition!; Clean Up Party*

- Last-minute modifications to robots.

- Final filming of robots.

- Testing robots in the exhibit space (Sage Lounge, 2nd floor of Science Center).

- **Robot Exhibition**: Dec 7, 4:30 – 6 pm in the Sage Lounge.

- **Cleanup Party: Friday Dec. 10 1:30 pm – 4 pm** in SCI L024. Cleanup of room L024, accompanied with pizza and ice cream**. All students are** *required* **to help with the clean up!**

- **Final Design Blogs due Friday Dec. 10 at 5 pm.**