Robotics and Intelligent Systems for Social and Behavioral Science Undergraduates

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ABSTRACT

In this article, we share our experiences offering an original course entitled *Intelligent Systems* targeted at undergraduate social and behavioral science students. *Intelligent Systems* provides a rigorous introduction to robotics and surveys selected topics in artificial intelligence. This course is tailored to students with little mathematical background and no programming experience. We offer best practices and information from successful course components and ideas for tailoring course content to social and behavioral science students.

The motivation for this course comes from the wide interdisciplinary appeal of robotics and artificial intelligence. They have been leveraged to improve recruitment to the major and to expose students in other disciplines to computational thinking. However, no offerings of CS0 that exclusively cater to the large social and behavioral science population are available that focus on intelligent systems. Robots and AI systems are affordable and accessible to this group of students. We propose our solution to this problem and argue for offering multiple, interdisciplinary CS0 offerings.

Categories and Subject Descriptors

J.4 [**Computer Applications**]: Social and Behavioral Sciences—*economics, psychology, sociology*; K.3.2 [**Computers and Education**]: Computer and Information Science Education—*computer science education, curriculum, literacy*; K.4.1 [**Computers and Society**]: Public Policy Issues—*Ethics*; I.2.9 [**Artificial Intelligence**]: Robotics—*sensors, autonomous vehicles*

General Terms

Design, Experimentation

Keywords

Artificial intelligence, robotics, intelligent systems, curricula, interdisciplinary, multidisciplinary, recruitment, retention, social and behavioral sciences

ITiCSE '10 Bilkent, Ankara, Turkey

1. INTRODUCTION

In this paper, we discuss our experiences offering an original course entitled *Intelligent Systems* targeted at undergraduate social and behavioral science students. There have been a substantial number of course offerings combining robots and Computer Science with engineering and humanities disciplines. However, there is a significant shortfall in the offerings that are intended largely for social and behavioral science student audiences. These students are well poised to benefit from the material as they will serve roles as policy makers and researchers using and evaluating this content.

Small college Computer Science departments struggle to offer a comprehensive schedule of courses. We have traditionally offered a single non-major course, often referred to as CS0, aimed at a general student from any non-Computer Science major. Often, our departmental service course is not successful at capturing the interest and attention of non-major students. And, the material in CS0 is often not what technically savvy students are searching for. At Wheaton, our curriculum dictates that we offer pairs of courses that span disciplinary boundaries, called *Connections*. We have intentionally built our halves of connected courses to replace our CS0 offering and tailored them to complement our own research programs. We have increased the number of non-major courses geared toward other disciplines and offered by faculty teaching in their own research area. The goal is twofold: 1) improve recruitment to the Computer Science major and minor; 2) increase the number of students taking Computer Science at the College.

The *Intelligent Systems* course provides an introduction to robotics and a survey of selected topics from artificial intelligence. Unlike the Artificial Intelligence-area courses we offer for majors, this course is available to students with no programming experience. Without an explicit computational thinking requirement in the College's curriculum, we are still able to include those concepts in the courses for non-majors. We equip students with the technical know-how to program a modern robotics platform, iRobot's Create robot, using Alice. Programming exercise topics range from mimicking simple animal behaviors (e.g., wall following) to discovering the emergence of swarm behaviors. On the theoretical side, students critically analyze seminal articles in AI and related areas to ultimately be better equipped to address Alan Turing's question, "Can machines think?"

We explicitly created this course to increase the enrollment of social and behavioral science students in our course offerings, and to foster scholarly collaborations between faculty in those disciplines with Computer Science. The wide-reaching appeal and interdisciplinarity of robotics and artificial intelligence drove its selection as the course subjects. To further increase the viability of the course, it also satisfies one of the College's curriculum distribution requirements in quantitative analysis (QA). The QA requirement exposes students to formal symbolic systems and mathematical models. To make the course accessible, no programming experience is expected and no college-level mathematical background is required. In the initial offering of the course, students from Linguistics, Psychobiology, Psychology, Music, and Economics enrolled along with students from Biology, Bioinformatics, and our study-abroad program.

Wheaton holds the honor and distinction of being the nation's first four-year baccalaureate institution of higher education for women. Since 1988, our institution has been coeducational, but it remains committed to its history and legacy. The Computer Science major began after coeducation and lacks the same alumnae base as other STEM disciplines at Wheaton. Because of this and generally, we are conscious of the need to increase the participation of women and students from underrepresented minority groups in Computer Science. In part, we are targeting this course at the larger groups of social and behavioral students to increase their level of participation.

In the following sections, we review the literature about teaching with robots and intelligent systems at a variety of levels and to diverse audiences. Next, we expand on the notion of *Connections* and discuss how the program is implemented at Wheaton College. Then, we detail *Intelligent Systems*, the course materials used, and the approach taken to make the material accessible. Finally, we conclude with some lessons learned and point to changes for future offerings of the course.

2. RELATED WORK

Popular science and press coverage of robotics and artificial intelligence indicate broad appeal, and students outside of the Computer Science major seem both curious and eager to learn more about the topics. Enticing students with hands-on entry-level components is now, more than ever before, particularly affordable and accessible [4].

The popularity drives coursework for recruitment and retention inside the major with, for example, robotics as the unifying theme for the standard AI class [11]. Other approaches use robotics in CS1 [9] or individual student projects [8]. Similarly, a significant number of intelligent systems-infused offerings are directed at students outside of Computer Science. Several approaches focus on specific pairings of disciplines like Computer Science and Art [26] or Computer Science and Mechanical Engineering in specialty courses [21, 22]. However, most contact with non-major students happens in a CS0-style course and often some portion of the content is devoted to AI [5]. Or, CS0 has its content tailored for a specific other discipline [6].

Particularly at small colleges, there are few opportunities to offer courses for non-majors. *Intelligent Systems* is distinct in form and purpose from these other offerings for two reasons: 1) the course content is a rigorous technical introduction to robotics and artificial intelligence without prerequisites; 2) it serves as a Computational Thinking (CT) [24] course targeted at students in the social and behavioral sciences with, we argue, a compelling set of topics with greater appeal than a traditional or targeted CS0 offering.

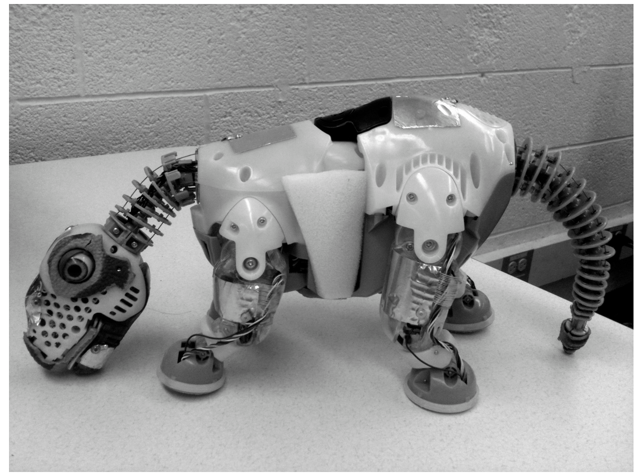

Figure 1: A Partially Dissected Pleo Dinosaur Robot from Ugobe

3. CONNECTIONS

In December of 2001, Wheaton implemented an innovative curriculum called *Connections* [14]. The *Connections* curriculum charges the Faculty with designing and offering pairs of courses across disciplinary boundaries. The combinations must come from traditionally disparate disciplines (e.g., Chemistry's *Edible Chemicals* and Anthropology's *Feast or Famine: The Ecology and Politics of Food* in a connection named *Food*). Mathematics and Computer Science is considered its own academic area at Wheaton and is striving to build connections with the other academic areas: creative arts, humanities, history, natural sciences, and social and behavioral sciences.

The Mathematics and Computer Science department already offers courses with most of the other academic areas, but not the social and behavioral sciences. For example, the connection *Computer Architecture* links our Computer Organization and Assembly Language course with the Physics Department's *Electronic Circuits* course.

We connect with students in the Arts by offering a course entitled *Web Programming, Graphics, and Design* linked with *Graphic Design I*. In our course, students use tools (e.g, Dreamweaver, Flash) and delve into the data they are using and creating. They also learn to program with ActionScript [7]. To connect with the humanities in a connection called *Computing and Texts*, we have a course entitled *Computing for Poets* linked with English's *Anglo-Saxon Literature* or *J.R.R. Tolkien*. Student process corpora and learn to program in Python. We also have a strong connected offering with the natural sciences and philosophy. A cross-listed course in Computer Science and Biology entitled *DNA* links with the Philosophy department's offerings *Ethics* and *Medical Ethics*. Students learn to program in Perl with a focus on large corpus processing and regular expressions [13].

To address the dearth of offerings for social and behavioral science students we specifically developed a novel course to connect with courses in that area. We plan to link *Intel-*

ligent Systems with *Learning and Memory*, *Consciousness* and *Comparative Animal Behavior* in the Psychology department and at least one course in the Sociology department. This connection makes a compelling, timely Computer Science course attractive and available to the largest group of non-science students on campus. It is important to note that while these courses satisfy a College curriculum requirement, any student may register for the class independently. Also, as our liberal arts curriculum has traditionally fewer requirements than other types of schools, the course offers another accessible option in the sciences to all students.

Connections has been successful at expanding student learning, but it has also benefited the department in other ways. One, our enrollments increase because of the connected course requirement. Two, connected courses have higher enrollments of women [14]. Three, being deliberate about formalizing interdisciplinary course offerings has led to interdisciplinary research and sponsored projects [13].

4. COURSE DESIGN

The course is designed in a way that it is accessible to students with no prior mathematical or technical background. The first half of the course is a rigorous introduction to robotics beginning with fundamental paradigms and then adding components to build larger systems. Students begin understanding the different robot control paradigms starting with a decomposition of the Sense-Plan-Act robot control primitives. We focus initially on *Acting*, the components, effectors and actuators, that enable robots to interact with their environments, and the way they interact with the environment to acheive locomotion.

To give students hands-on experience, we use Ugobe's Pleo robot as an example of an embodied, autonomous system. Pleo is a quadruped robot with more than a dozen motors and a speaker. Initially, Pleo has a skin and students anthropomorphize the robot before we remove the outer shell to reveal and explore the mechanical components (see Figure 1). We also consider iRobot's Create, the primary platform for the course, and its differential drive system (see Figure 2). Then, we move to *Sensing* with Pleo and the Creates. We selected the Create robots as the primary platform for the course for three reasons: 1) controlling the robots is trivially cross-platform; 2) the cost of the platform and connection is low per unit; and 3) there are substantial resources available online with a small learning curve. We explore the exteroceptive and proprioceptive sensors on both, challenge the limits of the sensor capabilities, and begin attempting small programming tasks using a modified version of Alice [23]. For example, to test the wheel encoders of the Create, students are tasked with writing a program that drives the robot in a square shape indefinitely. The exercise serves as a segue into discussion of dead reckoning, localization, and navigation.

The second half of the course builds on students' knowledge of *Sensing* and *Acting* in autonomous robotic systems to focus on *Planning*. We broadly explore intelligent systems and related topics. There are a wide variety of topics to select from, but we infuse how to build knowledge representations throughout the topics we discuss and analyze. We cover single-player and multiplayer games, while focusing on developing heuristics for simple games (e.g., Connect Four) and applying those skills to robotics domains. We spend several weeks on approaches to natural language processing and machine translation.

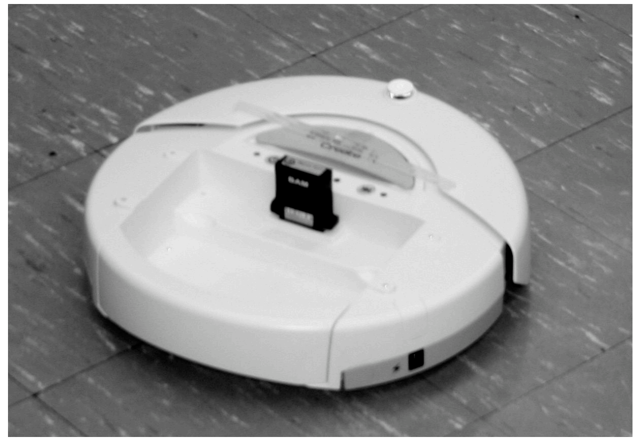

Figure 2: iRobot Create Robot with Bluetooth Adapter Module

Another component of the Wheaton curriculum is exposure to non-native languages, and all students have some proficiency in a second language. Students use that knowledge to evaluate available machine translation systems (e.g., Google Translate). They also analyze transcripts of Turing-text contestants to discover real-world examples of intelligent systems failing to properly handle ambiguity and other language phenomena.

After studying language in isolation, we bring back the concept of embodiment and the grounded acquisition of native tongues with content about speech and speech processing. We cover emergent behaviors of complex systems in the context of robot swarms and artificial life. The semester is rounded out with a discussion of robot ethics and the use of autonomous vehicles in military and humanitarian domains. Each topic is accompanied with relevant literature and significant class discussion.

4.1 Reading Assignments

In addition to readings from the course textbook [15], the course offers an opportunity to read seminal articles and explore interdisciplinary literature in a seminar style. A significant amount of class time is spent discussing the readings and covering fundamental technical details to understand the readings. Again, intelligent systems is a field filled with accessible articles that are grounded out in human-intelligence examples – reading assignment geared toward non-computer scientists and computer scientists alike.

In learning about robot control paradigms, students read Brooks' article on the subsumption architecture [3]. We vigorously debated the arguments of strong and weak artificial intelligence after reading Turing's original *Mind* article [20] and Searle's Chinese room argument [18]. These discussions spurred students to inquire about other topics outside of class. These independent investigations informed other class discussions. For example, many students were intrigued and independently explored papers on the potential impacts of singularities [12]. We did not experience this in the standard CS0 course offering.

The students were particularly interested in robot swarms and emergent behaviors. We read Reynolds' boids article

[16] and constrasted his boid flocks with examples of real-world flocking examples. Students experimented with Conway's *Game of Life* and read selections from Wolfram's *A New Kind of Science* [25] to see other applications of cellular automata.

To discuss ethical issues raised when utilizing autonomous robots in the battlefield, we considered competing perspectives including Arkin [1] and Sharkey [19]. We also discussed how robot decisions are made while talking about games and game playing [17]. The conversation was easily contextualized being in the midst of media stories about unmanned aerial vehicles.

4.2 Experiential Learning

Accompanying the lecture and seminar sessions, we spent a substantial amount of time with hands-on laboratory activities and experiential learning. To delve right into world of problem solving with limited information, students explored Zach Dodds's Picobot, a simulated minimal robot with local north, south, east, and west sensing information. Programming tasks for the Create robots with Alice included: 1) designing an algorithm to follow a wall in an arbitrarily shaped room; 2) designing an algorithm to have the robot navigate a black strip on the ground; and 3) a task to demonstrate the challenges associated with dead reckoning. The robots and software are available for use outside of class, and the Bluetooth Adapter Module (BAM) allows any laptop with a Bluetooth connection to act as the robot brain. Interestingly, questions about *where* computation occurred became a teachable moment. Students struggled with the Creates being called robots when the program controlling the robot was running on a desktop computer as opposed to the onboard processing unit or attached laptop.

In addition to the Create robots and Pleo, the students were responsible for being informed about intelligent systems news. Using a Twitter account, `http://twitter.com/comp198298`, with a shared password, student posted links to relevant new stories, articles, and videos of intelligent systems in action. This source of information typically let the class begin with a one-minute reference to a current event, research finding, or demonstration that led into the current class topic.

There were several hands-on experiences to experiment with language. Each student used their natural language experience to translate a text from English to other languages. Using the class-generated parallel corpus, we explored statistical machine translation with each student supplying their own language expertise. We covered different models of machine translation, Bayes rule, and other techniques used to process large parallel corpora. In addition, students completed Knight's exercise in "alien" language translation [10]. To better understand language processing not involving text, we considered speech processing. To gain hands-on experience, we used the tool Praat to analyze speech that we produced in class. Students record themselves producing speech and use the tool to analyze and understand features used in speech processing.

Given our proximity to some major robotics companies, we were able to have an on-site visit to iRobot Inc. We received a tour of their robot museum collection and students gained exposure to military-grade robots and technologies. After the tour, we met with an engineer to discuss broader robotics topics, other iRobot product functionality, and experiences working as an engineer.

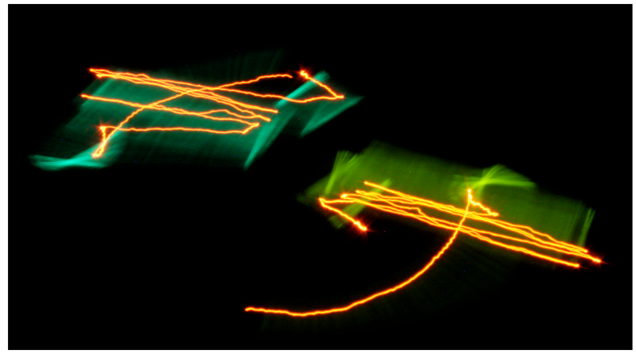

Figure 3: Extended Exposure Photograph of iRobot Create Pair Square Dancing

4.3 Group Projects

During the second half of the semester, student groups propose and implement a project of their own design. Students have access to a variety of robotics platforms (e.g., LEGO NXT, iRobot Create, and Arduino kits), other computing resources outside of class, and Computer Science majors with programming experience. One group was interested in learning more about machine learning and proposed a project to build a system that learns from user input about the Wheaton campus. They devised and implemented a decision tree learning system that operated for a game of "20 Questions" about locations on campus.

Another group took the abstract ideas they learned about robot swarms and applied those to an interesting domain with a creative result. Each iRobot Create robot was programmed to perform specific square dancing moves (e.g., Forward and Backward, Do-Si-Do). In addition to filming the swarms, the group placed different colored glow sticks on the robots in a dark room and took extended-exposure photographs (see Figure 3 for one example involving two robots). One group had less success with the Create robots and ran up against the technological limitations of the tool trying to build a real-world PONG player.

Finally, a group was inspired by Valentino Braitenberg's robot gedankenexperiments [2]. They replaced the components of an early RadioShack Robie toy with an Arduino-powered system and motor shield. Using photoresistors, the group built Braitenberg's third vehicle, *Love*, which accelerated toward a lightsource. It also served as an opportunity for the students to instruct their fellow students. To complete their project, they gained experience building electronic circuits, and shared some of those skills with the class.

5. STUDENT EXPERIENCES

The feedback from students was overwhelmingly positive. On a scale of $1-5$ (5 being the highest value; 1 being the lowest), students rated the overall course a 4.44. Some students expressed that the course would benefit from a laboratory period in addition to the normal class meeting periods. This speaks to the evaluation comments asking for additional "hands-on" work in the class and access to "more robotic gadgets." Also, some students mentioned that we should "put the programming first" and that spending more time up front on programming would be beneficial. We tend to agree and plan to spend the beginning portion of the next offering focused on introductory programming in Alice or some other appropriate language (e.g., Python).

6. CONCLUSIONS

The course did what we wanted: 1) it brought students from the social and behavioral sciences to a class in the department; 2) it exposed students taking one Computer Science course to content they were easily engaged with; and 3) it expanded the pool of students that might continue on to CS1 or a traditional AI course in the future. We do not yet have enough data to suggest that these connected course offerings lead to increases in major or minor students. However, we are increasing the number of students taking a computational thinking course at the College without an explicit requirement for CT.

That said, we learned several lessons from the class. First, the course needs an additional laboratory session to augment the lecture/seminar sessions. The laboratory would serve the course in two ways: 1) it provides a significant block of time to work on larger tasks with more interaction; 2) it doubles as a time where groups can meet to work on their projects in the second half of the course.

Second, the gap in cost and functionality between hobbyist robot kits, Creates, and toys and research robots is gigantic. Students quickly realize they are working with relatively impoverished resources with minimal support (e.g., APIs, sensors). To address this, we are actively pursing ways of funding more substantial robots that serve dual purposes as teaching robots and research robots.

Finally, space is of critical importance. Students need dedicated, secure space to work and store projects and assignments. Additionally, having a permanent space during the semester would foster more inter-group collaboration and raise the quality of the final products.

7. ACKNOWLEDGMENTS

We would like to thank the staff at iRobot Inc. for opening their doors and graciously taking time to share their work with us. Also, we would like to thank the Office of the Provost at Wheaton College for generous funds to acquire the iRobot Create robots, transportation to iRobot, and funding for future teaching/research robots.

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