Teaching Robotics Everywhere

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The Robotics Education Workshop (http://projects.csail.mit.edu/rss/RobotEd/) took place in connection with the 2005 Robotics Systems and Science (RSS) symposium (http://www.roboticsconference.org/) at the Massachusetts Institute of Technology (MIT) on 11 June 2005. It was organized by John Leonard, Una-May O'Reilly, Nick Roy, Daniela Rus, and Seth Teller.

The workshop's main goal was to discuss what it would take to turn robotics into a core course that can be taught in every accredited CS, ME, and EE undergraduate program in the United States and elsewhere around the world. We were inspired to organize this workshop during an introductory robotics course we have been developing as a team (http://courses.csail. mit.edu/6.141) and were encouraged by Hal Abelson.

There are many reasons why we believe now is an important time to consider teaching robotics broadly. The computing revolution is bringing computers closer and closer to interactions with the physical world. We have seen the progression from mainframes to desktops to laptops to pervasive computing by networking. Most of today's computers have integrated sensors, such as microphones, primitive motion sensors to park the disk drive, light sensors to detect when to automatically illuminate the keyboard or dim the screen, and cameras to collect images from the surrounding environment.

Recent advances in the cost, size, performance, and capabilities of actuators show us that actuation will become native to a computing environment so that today's personal computers (PCs) will become tomorrow's personal robots (PRs). Robotics brings an interesting perspective to computer science education as it naturally puts together continuous and discrete computation and provides an opportunity to reason about error and uncertainty, an important new topic in the study of computation at the undergraduate level. Last but not least, the love of robots is as pervasive as can be.

Robotics is hard to teach because the expertise in robotics is concentrated at a few institutions. And, there are no established curricula, no robust and inexpensive teaching platforms, and no collections of labs and projects with solutions. Teaching robotics well relies on integrating together ME, EE, and CS topics; creating a balanced syllabus is a huge challenge.

Yet, robotics provides the perfect educational tool for introducing students to embedded systems and computation for interacting with the physical world, and to making intelligent autonomous machines. Several universities have already introduced special topics courses on robotics. The curricula and hardware platforms for these courses are quite varied, and the goals of the courses differ across ME, EE, and CS departments. We wished to leverage this excellent body of knowledge and discuss how to develop an integrated approach to teaching robotics that would train students simultaneously in foundational aspects of designing, controlling, and programming robots and embedded systems.

To this end, the discussions at the RSS education workshop were focused on 1) evaluating the state of the art for undergraduate robotics education, 2) discussing how to build on this experience toward a broad integration of robotics in the undergraduate curricula, and 3) discussing how to best share course materials.

Over 30 professors from universities and colleges in the United States, Europe, and Asia met for a full day. The program alternated presentations on existing courses and educational material with lively discussions on the key issues of integrating robotics in an undergraduate curriculum. The workshop program included presentations by Gaurav Sukhatme (University of Southern California), Mark Yim (University of Pennsylvania), Illah Nourbakhsh (Carnegie Mellon University), Brad Nelson (ETH-Zurich), Jonathan Bredin (Colorado College), Holly Yanko (University of Massachusetts, Lowell), Matthew Stein (Roger Williams University), Matt Mason (Carnegie Mellon University), John Hollerbach (University of Utah), Nick Roy (MIT), and Stewart Tansley (Microsoft). Three discussion sessions focused on 1) hardware kits, software packages, and lessons learned (moderated by Una-May O'Reilly, MIT); 2) integrated syllabus and projects (moderated by Seth Teller, MIT); and 3) what to share and how (moderated by Daniela Rus, MIT).

The presentations were all exciting, inspiring, and filled with interesting lessons learned, and workshop participants were highly engaged in the discussion sessions. The most important outcome was a general goal of creating an open repository of robotics course materials in order to better coordinate the teaching of robotics across universities. Such a repository would enable the sharing of course materials. By providing easy access to teaching materials, the teaching of introductory robotics courses everywhere will be facilitated, and robotics will become a core component of computer science and engineering academic programs. This will strengthen the education and research activities for our field.

More specifically, the participants discussed the possibility of developing an open repository of robotics course materials similar to MIT's OpenCourseWare (OCW) initiative. This repository would contain a suite of robotics curricula for teaching all aspects of robotics, ranging from undergraduate introductory courses

(continued on page 94)

CALENDAR

2006

2–3 Mar. HRI2006: Human Robot Interaction. Salt Lake City, Utah, USA. http://www.HRI2006.org

15–19 May. ICRA2006: IEEE International Conference on Robotics and Automation. Orlando, FL, USA. http://www.icra2004.org

17–19 May. INCOM: IFAC Symposium on Information Control Problems in Manufacturing. Saint Etienne cedex, France. http://www.emse.fr/incom2006/

7–9 June. CIS & RAM: IEEE International Conferences on Cybernetics & Intelligent Systems and Robotics, Automation, & Mechatronics. Bangkok, Thailand. http://www.ntu.edu.sg/cis-ram/

7–9 June. IV2006: IEEE Intelligent Vehicle Symposium. Tokyo. http://www.ycvl.iis.u-tokyo.ac.jp/iv2006/

21–23 June. WCICA2006: World Congress on Intelligent Control and Automation. Dalian, China. http://www.wcica.info

25–28 June. ICMA2006: IEEE International Conference on Mechatronics and Automation. Luoyang, Henan, China. http://www.ieee-icma.org/

6–7 July. ASER2006: Workshop on Advances in Service Robotics. Vienna, Austria. vincze@acin.tuwien.ac.at

16–19 Aug. RSS2006: Robotics: Science and Systems 2006. Philadelphia, PA, USA. http://www.roboticsconference.org/

20–23 Aug. ICIA 2006: IEEE International Conference on Information Acquisition. Weihai, China. http://www.ia-ia.org

22–25 Aug. SSRR2006: IEEE International Workshop on Safety, Security, and Rescue Robotics. Gaithersburg, MD, USA. http://www.isd.mel.nist.gov/ssrr2006.

25–28 Aug. ISRA: 5th International Symposium on Robotics and Automation. Pachuca, Hidalgo, Mexico. Rene.Mayorga@uregina.ca

6–8 Sept. 2006 RO-MAN: 2006 IEEE International Workshop on Robot and Human Interactive Communication. Hatfield, United Kingdom. http://www.ro-man.org/

6–8 Sept. 15th IEEE International Workshop on Robot and Human Interactive Communication. De Havilland Campus, University of Hertfordshire, UK. K.Dautenhahn @herts.ac.uk

6–8 Sept. SYROCO2006: 8th International Symposium on Robot Control. Bologna, Italy. http://www.syroco2006.deis.unibo.it

12–14 Sept. 4th IFAC Symposium on Mechatronic Systems. Wiesloch/Heidelberg, Germany. http://www. mechatronics2006.com

8–10 Oct. CASE 2006: IEEE International Conference on Automation Science and Engineering. Shanghai, China. http://www.ieee-case.org/

9–15 Oct. IROS2006: IEEE/RSJ International Conference on Intelligent Robots and Systems. Beijing, China. http://www.iros2006.org/

4–6 Dec. Humanoids 2006: 6th IEEE-RAS International Conference on Humanoid Robots. Genova, Italy. sandini @unige.it

5–8 Dec. ICARCV 2006: 9th International Conference on Control, Automation, Robotics and Vision. Singapore. http://www.icarcv.org/

17–20 Dec. 2006 ROBIO: IEEE International Conference on Robotics and Biomimetics. Kunming, China. http://www.robio2006.org/

2007

10–14 Apr. ICRA 2007 IEEE International Conference on Robotics and Automation. Rome, Italy. http://www.icra07.org/

EDUCATION

(continued from page 15)

to project courses and graduate courses. Example materials for each course include syllabi, lecture notes, laboratory specifications, exercises, assessment materials, and reading materials. The Web site will be searchable, browsable, and open for downloads.

The Web site will be seeded with some course materials and moderated for contributions so that anyone can contribute. Imagine a resource (like Wikipedia) with rich interfaces, providing both teaching resources and discussion forums for teachers and students at all levels. These materials could be disseminated by organizing tutorials with the goal of hands-on practice during robotics conferences and symposia.

The course materials could be organized as a collection of modules within a graph structure that could be navigated in different ways, each sequence corresponding to a syllabus for a robotics course. All of the modules should be developed on the same robot platform, using the same software infrastructure. Hardware and software specifications and packages will be provided. Each module will have lecture materials, specifications for laboratory exercises, and solutions. Sample modules may include: Basic Electronics for Robots, Basic Mechanics for Robots, Basic Control for Robots, Perception and Visual Methods for Robots, Measurements and Error Analysis for Robots, Localization for Robots, Planning for Robots, Coordination for Groups of Robots, Grasping and Manipulation for Robots, Sample Integrated Projects, and Sample Grand Challenge Projects.

There is a lot of enthusiasm for the creation of a shareable repository of course information so that robotics can be taught broadly. Now we just need to find the resources that will allow us to do it!