Educational Robotics

Assessment of the State of the Art in the US

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Topic Summary

- Design of robotic hardware, software, curricula and evaluation methodologies that enable the use of robots in learning environments.
  - Application: Robotics for technology literacy: application to informal learning environments (e.g. museums, homes)
  - Application: Robotic curriculum as an ingredient in formal educational venues: Pre K-12, undergraduate, and graduate levels
  - Application: Robot contests as challenge-based, experiential learning opportunities cross-institution
  - Technology: Hardware and microprocessor design for high-reliability robotics in hostile environments (i.e., kids!)
  - Technology: Software development environments for educational robot programming
  - Technology: System design and methodology for meaningful educational efficacy evaluation

Partial list of laboratories (1)

- Carnegie Mellon University- The Robotics Institute
  - Andrew's Leap and C-MITES summer and weekend courses for middle school and high school students.
  - NREC RoboCamp for high school students (Robin Shoop)
  - CMU West Robotic Camp for underprivileged high school students in Mountain View, CA.
  - Undergraduate and graduate courses, including degree-granting MS and PhD programs in Robotics
  - Robotics Educational Laboratory open to all robotics research, including Matt Mason, Yoky Matsuoka, Illah Nourbakhsh, Chris Atkeson, etc.
- University of Oklahoma - Intelligent Systems Program
  - Undergraduate degree concentration across CS, CE, EE, AE and ME focusing on robotics. Robotics projects from intro to engineering through capstone level. (D. Miller, D. Hougen, A. Fagg, S. Comurri, etc.)
- Swarthmore College – Lisa Meeden and Bruce Maxwell
  - Educational robotics program for undergraduates including both distant, high quality research robots available over the internet, and local robot "clusters" used in programming laboratories.

Partial list of laboratories (2)

- Stanford Robotics Lab – Kurt Konolige
  - Robot building and programming coursework for 8+ years at Stanford, culminating in high-competence student-programmed robots using SLAM.
- Columbia University – Elizabeth Sklar
  - Using RoboCupJunior, a national LEGO-based robotics teaching and contest venue as a means to reach out to K-12 students nation-wide. Themes include soccer, rescue, and dance. A teacher-training national conference has been developed to coincide with the event.
- University of Southern California – Maja Matarić
  - Using LEGO and Handyboards to teach introductory robotics at the university level, with a public (publicized and televised) contest each semester held at the California Science Center. The curriculum is being adapted for after-school K-12 robotics workshops.
  - Using LEGO Mindstorms as a platform for adding robotics into middle school science classes, as part of an NSF RET grant. Curriculum available on the web.
  - Introductory robotics textbook to appear in 2005, aimed at K-12 teacher training and undergraduate students.
  - Undergraduate and graduate courses, MS & PhD degree programs.
- NASA Ames – Robotics Clearing House
  - A Web repository of curricular and other K-12 educational robotics materials

Partial Laboratories (3)

- KISS Institute for Practical Robotics
  - Robots in Residence program for elementary schools. Roboticist spends several days at a school giving assemblies and working with students in small groups to understand and build robots
  - Botball Teacher Training short course for middle and high school teachers that gives teachers the fundamentals of robotics and C programming
  - Botball Middle and High School Program provides a year long curriculum and set of activities including team and individual research activities, design, construction and programming of cooperative teams of robots, performance based and head to head robot contests
  - National Conference on Educational Robotics, a professional style conference where the technical talks are given by students and secondary school teachers.
  - Interactive robot programming environments, standard programming languages with a simple, friendly and interactive IDE and extensive library of robot functions.
  - Robot kit development for stand alone construction and programming of autonomous robots.
  - Assessment of students and teachers through a series of online and paper instruments that track class progress on their robot projects and the impact the activities have on the students' development and educational plans.

Major Theoretical Accomplishments

- Embedded processor architectures for rapid robotic prototyping with high competence
  - Fred Martin – The 6811-based Handyboard, together with KIPR's (Randy Sargent) Interactive C programming environment serves as a significant improvement over prior architectures for robot programming and rapid prototyping.
- Interpreted robot programming software environments for education
  - Randy Sargent's and KIPR's Interactive C programming environment enables an architecture for seamless computer-based coding and joint computer-robot debugging
- Curricular development and evaluation
  - Illah Nourbakhsh, Maja Matarić - Development of K-12 curricula for in-school science classes using robotics as well as dedicated robotics courses, and after-school robotics workshops
- Educational psychology-based coding evaluation methodologies for formal educational robotics assessment
  - Kevin Crowley and Illah Nourbakhsh's application of educational psychology coding techniques to mobile robot educational settings in informal and formal venues.

Major Practical Embodiments

- Museum exhibit demonstrations of social robotics and educational results
  - Sebastian Thrun (Stanford), Illah Nourbakhsh (NASA/CMU)
  - Short-term (2 week) and very-long-term (4 year) educational robotic exhibits in museums. Long-term demonstration of quantitative learning results in visitors
- Challenge-based mobile robot programming courses
  - Kurt Konolige (Stanford), Illah Nourbakhsh (NASA/CMU), Maja Matarić (USC), etc.
  - Robot construction and programming courses taught for more than 10 years at every institution, garnering consistently high student interest
- Fully instrumented robotic education programs, resulting in formal educational evaluation
  - Nourbakhsh; Executed an instrumented robotic class for high-school students and an instrumented exhibit for the Smithsonian NASM and SF Exploratorium with quantitative educational assessments. 40 robots built for each application.
- Robot tournaments for students
  - Broad dissemination of cross-site robot contests for secondary levels and beyond
  - See next slides
- Public domain web-distributed simulation and software
  - Realistic yet accessible simulations on the web (e.g., playerstage.sourceforge.net)

Tournaments & Contests

- Two successful problem formats:
  - Fixed problem: allows student teams to build on previous years' work
  - New problem: allows new students to start fresh and keeps repeating students engaged
- Performance formats for all types of competitive personalities:
  - Performance based: robots compete against the clock or a fixed performance metric. Performances are ranked at the end
  - Head to head: robots compete directly against one another and only have to outperform their opponent of the moment
  - Ungraded: robots do what they do and are appreciated for it

Partial List of Educational Robot Tournaments

Tournament	Problem Format	Performance Format	Discipline Emphasis	Primary Team Organizers
AAAI	Fixed & New	Performance	CS	Grad students
Best	New	Head to Head	ME	Secondary School Teachers
Botball	New	Performance & Head to Head	CS	Secondary School Teachers
Firefighting	Fixed	Performance	System Eng	Robotics Enthusiasts
FIRST Robtics	New	Head to Head	ME	Industry
FIRST LEGO League	New	Performance	System Eng	Middle School Teachers
NCER Showcase	Undefined	Ungraded	Problem Solving	Secondary School Students
Robocup	Fixed	Head to Head	System Eng	College Students
RobocupJr	New	Ungraded?	Problem Solving	K-12 students
Robofest	Undefined	Ungraded	Problem Solving	Robotics Enthusiasts

Educational Robotics State of the Art, July 2004 NSF

“Classroom” robots (1)

- Education through play
  - e.g., KinderBot (Fisher-Price)
- Classroom teaching tool
  - e.g., ER1 (Evolution Robotics)
- Motivational School/Museum Assemblies
  - e.g., Asimo (Honda); MDM (LifeSkills4Kids)
- Tele-education
  - e.g., Pebbles (Telbotics - Canada)
- Special Education - Inclusive Classroom
  - e.g., CosmoBot (AnthroTronix, Inc)

“Classroom” robots (2)

FIRST - “For Inspiration and Recognition of Science and Technology”

- FIRST Robotics Competition
  - Partnerships between schools, industry, and universities; 20,000 high school students in 2004.
- FIRST Jr. Robotics - “LEGO League”
  - Partnership between students ages 9 to 14, FIRST, and Lego Company.
- FIRST Place - reconfigurable science and technology laboratory space in NH
- Woman in Science and Technology Forum

Relevant Publications

- Books
  - *Constructionism*, S. Papert & I. Harel, 1991
  - *Mobile Robots: Inspiration to Implementation*, J. Jones & A. Flynn, 1993
  - *Introduction to AI Robotics*, R. Murphy, 2000
  - *Robots for Kids,* A. Druin & J. Hendler, 2000
  - *Mechanics of Robotic Manipulation*, M. Mason, 2001
  - *Introduction to Autonomous Mobile Robots,* I. Nourbakhsh & R. Siegwart, 2004
  - Robot Companions: Mentorbots and beyond, E. Oliver Severin, 2004
  - *The Robotics Primer*, M. Matarić, MIT Press, 2005
- Articles
  - AI in Space: Creating Autonomous Roboticists Miller & Stein, IEEE Intelligent Systems v. 16, #2, pp. 20-23, 2001.
  - "A Survey of Socially Interactive Robots," Fong, Nourbakhsh & Dautenhahn. RAS, 2003.
  - "The Robotic Autonomy Mobile Robotics Course: robot design, curriculum design and educational assessment," Nourbakhsh, Crowley, Bhave, Hamner, Hsiu, Richards, Wilkinson. AURO, in print.

Unsolved Problems and Challenges

- Raising the competence of mobile robots at a low price point: vision-based environmental perception
- Low-cost, effective manipulation for educational robots and curriculum
- Cumulative capability: robotic platforms with educational value across the range of levels, through graduate school. All at a low cost.
- Development and public access to K-12 age-appropriate curricular materials and lesson plans
- Accessible K-12 teacher training venues and tools
- Education as a market for robots and robotic applications

Research Goals

- Develop high capability robot controller which:
  - Has enough processor power, memory and connectivity to allow it to be used to explore more than toy problems
  - Is easily interfaced with a wide variety of sensors and effectors (e.g., Handy Board)
  - Can be programmed with student friendly environment, in a standard programming language (e.g., IC4)
  - Interface easily with high bandwidth sensors (e.g., audio & video)
  - Has low price point (e.g., RCX)
- Create a simulation environment which:
  - Can be distributed over the web
  - Is open and free (or at least donation ware)
  - Can be used for K-12+ teaching of programming, mechanics and system engineering using only virtual hardware

Accomplishments in Other Countries

- Long-term, refined undergraduate challenge-based robotics curricula at the Swiss Federal Institutes of Technology (Roland Siegwart et al.)
- RoboCup penetration (originated in Japan) now popular in US and Europe. (Most widely accepted US tournament outside of the US is Trinity Firefighting. Tournaments with "NEW" game format (e.g., FIRST & Botball) are not widely accepted outside of US).

Primary Goals for US

- Encourage more schools to participate in one or more of the existing robotics programs
  - For many of the programs, funding is available if schools sign up early and ask for funding assistance
  - Many programs do everything regionally, so only minimal travel is needed
  - School administrations need to support their robotics teams with the enthusiasm and resource commitment they give to sports teams (but robotics should not be confused with sports, robotics directly improves academic performance)
  - Teachers need to be recognized for their efforts in this area and encouraged to disseminate results and developed materials
  - Conference/forum needed for the community to interact (researchers and users, university & K-12)