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Robotics competitions in the classroom: enriching graduate-level education in computer science and engineering

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ABSTRACT: This article presents a novel approach to using robotics competitions for graduate-level education in computer science and engineering. The proposed course introduces robotics competitions as a powerful engineering educational tool at the graduate level by encouraging educational goals that are appropriate for the academic and intellectual level of graduate students. The course focuses on mentoring graduate students to be scholars and on mentoring graduate students to be themselves mentors. The course also provides academic staff with an effective and efficient method of assessing these educational goals directly within the framework of a robotics competition, taking advantage of the professional evaluation and feedback inherent within each stage of the competition. The proposed course was offered at the University of Kansas in the Spring of 2008 and organised around the International Conference on Robotics and Automation (ICRA) Space Robotics Competition. Based on the results of the students' research and feedback from their academic publications and presentations, this graduate course has been shown to be effective.

Keywords: Robotics for education, robotics competition, graduate education, engineering education

INTRODUCTION

A novel method for encouraging robotics competitions in a graduate-level curriculum has been introduced in the Department of Electrical Engineering and Computer Science at the University of Kansas. The course represents a new approach to using robotics for education at the academic and intellectual level of graduate students in computer science and engineering. This newly designed course focuses on mentoring graduate students to be both scholars and mentors, and includes a novel method of organising and assessing these goals within the framework of a robotics competition.

Robotics has been demonstrated as an extension to traditional textbook and lecture-based education through its role as a learning collaborator, a learning platform and a learning focus [1]. Through these roles, robotics has served to interest students in science and engineering, to introduce them to real-world interdisciplinary applications, and to stimulate their intellectual development. As learning collaborators, social robots have assisted and encouraged the education of students, often serving as museum guides [2] or providing specialised interaction to students with disabilities, such as Autism Spectrum Disorder [3]. As learning platforms, robots have demonstrated the educational theories of constructivism and active learning, increasing student engagement and recall by providing a hands-on application for skills such as computer programming [4] and image computation [5].

As a learning focus, robots have taught skills specific to robotics [6], interested students in science and technology [7][8], and taught real-world teamwork and problem solving skills [9][10]. However, providing an objective measure of these benefits has proved more difficult for robotics in education than for other educational disciplines. While design-time assessment, formative evaluation and summative evaluation have been recommended to provide an objective measure of these benefits, a continued lack of standardisation, such as universally recognised textbooks and the often informal methods of using robotics in education has limited their use [1]. For these reasons, to simply include robotics in education has been discouraged, without first evaluating the effectiveness of including robotics for education [11].

Robotics competitions can provide an inherent framework for evaluating the benefits of using robotics for education by providing both clear objectives, as well as the criteria necessary for evaluating the objectives [12]. The competition framework [13] can also provide the immediate validation and feedback of experts in the field, such as through competition judges or Olympiad testing [14]. Past approaches to including robotics competitions in the classroom have added robotics to an existing curriculum [15], or focused on K-12 and university undergraduate levels in the Perry model of intellectual development [16], such as excitement in the sciences [17], building self-efficacy [18], and introduction to real-world interdisciplinary applications [19]. These approaches have stressed faculty involvement, shifting the burden of team leadership and project management to the faculty sponsor [15]. Even at the graduate level, the focus of robotics competitions for education often remains identical to competitions catering to the intellectual level of undergraduate students.

Past approaches have continued to be faculty-led and have not addressed education at the academic level of graduate students. This has been demonstrated by the difficulties that organisers of the Association for the Advancement of Artificial Intelligence (AAAI) robotics competition have faced in attracting graduate students to demonstrate novel and active research at the AAAI competition, and the continual shift in entries away from graduate students and towards undergraduate students [20].

The objective of this newly designed course is to encourage educational goals that are appropriate for the academic level of graduate students and to provide faculty with an efficient method of organising and assessing these goals. This represents a shift from practices in the past, which have focused primarily on K-12 and undergraduate levels of education and have assessed the course's educational goals through existing examinations [15], Olympiad testing [14], or student feedback forms [18].

Instead, this course takes advantage of a student-led team and the intellectual level of graduate students to provide a novel method for assessing these educational goals directly within the framework of a robotics competition. To demonstrate this new approach, the proposed course was offered in the Spring of 2008 and enrolled seven graduate students, including three Master's students in computer science, three PhD students in computer science and one PhD student in electrical engineering.

COURSE OVERVIEW

The proposed course was organised around the ICRA Space Robotics Competition, a new competition to showcase state-of-the-art research in the field of planetary exploration [21]. In recent years, planetary exploration has moved to the forefront of robotics research, such as the well-known Mars rovers Spirit and Opportunity [22].

The ICRA competition showcases advances in the sophisticated robot intelligence and autonomy that is necessary for planetary exploration by presenting challenges in mobile robot design, navigation and planning. These challenges focus on foundational problems in robotics, such as the simultaneous localisation and mapping (SLAM) problem, in which an autonomous robot must infer both the most likely map of its environment, as well as its own location within this map, given only the robot's unreliable odometry and noisy sensor readings from the environment.

In order to showcase this research in planetary exploration, the ICRA competition provides a 6 m x 6 m simulated planetary environment, in which autonomous mobile robots must navigate safely over the unpredictable gravel terrain and around obstacles while performing one or more of the competition events. These events include the *Onto the Surface* challenge, in which a robot must identify and navigate a safe path from a simulated lander onto the planetary surface, the *Map the Environment* challenge, in which a robot must explore the planetary environment and construct a metric representation of the planetary surface, and other challenges, such as *Extreme Navigation*, *Find the Robot* and *Bring Back Shiny Things*.

Each of these events provides a series of open-ended challenges and does not provide strict limitations or objectives for every challenge. Instead, a variety of research capabilities can be demonstrated by scoring each entry according to a style more similar to Olympic judging, which considers both the difficulty and execution of each entry. For example, in the 2008 ICRA competition, entries in the *Map the Environment* challenge demonstrated a variety of solutions, from a precise, 3D mapping of the terrain by a single, high-cost robot to a quick approximation of the terrain by coordinating multiple, low-cost robots.

The official course sessions consisted of two regularly scheduled weekly meetings, one with the academic staff and the students, and one with just the students. These meetings were equivalent to other three credit hour classes at the University which meet for two 75 minutes sessions per week for the semester. The faculty served as a facilitator, enabling two students to lead the rest of the students in the class. All the students were part of the same team; although, different sub-teams were formed to concentrate on different tasks, e.g., hardware components, software development, etc. Similar to other courses with team projects, the students met outside class time to accomplish the goals.

Because all students had undergraduate degrees in computer science, computer engineering or electrical engineering, they were able to form various teams depending on the needed tasks. Two of the students were designated to lead the team, one of whom was a senior PhD student based on the number of years in the graduate programme, and one student with many years of industrial experience as a computer scientist. The final grade for the course was based on each student’s contribution to the project, instead of the final outcome of the competition. All students received the highest letter grade.

Because the proposed course was organised around the ICRA competition, it was possible to adopt the requirements and timeline of the competition itself, resulting in three stages of educational goals within the course. In the first stage, the course adopted the competition's requirement that each entry showcase active research in the field of planetary exploration. During this stage, the course focused on a broad literature review of past and related work, ultimately focusing on a specific topic of interest and identifying an open research problem. In the second stage, the course adopted the competition's requirement that each entry demonstrate a novel solution to the identified research problem within a formal proposal to compete in the competition. During this stage, the course focused on defining, validating and implementing a novel solution to the open research problem and writing proposals for funding, travel and participation in the competition. In the third stage, the course adopted the requirements of participating in the competition itself. During this stage, the course focused on evaluating the final solution and presenting the research through formal mechanisms, such as presentations and publications.

The course was also able to provide an assessment of the educational goals directly within the framework of the robotics competition by providing academic staff with an efficient method for assessing the educational goals of the course, taking advantage of the professional evaluation and feedback inherent within each stage of the competition, as well as the results and feedback of presentations and peer-reviewed academic publications. This presents a more critical and unbiased assessment of the students' work in accomplishing the educational goals of the course, and is more appropriate for assessing these goals, which are difficult to measure objectively through examinations and student feedback forms. However, due to the inherent delays in receiving feedback from the peer-review process, the students' submission of articles for review may be considered sufficient for the purpose of assigning semester grades.

COURSE DESIGN

The proposed course introduces robotics competitions as a powerful educational tool at the graduate level by encouraging educational goals that are appropriate for the intellectual and academic level of graduate students. First, the course provides a foundation for mentoring graduate students to be scholars, including formulating research questions, performing independent research, writing proposals and presenting the research through formal presentations and publications. Second, the course provides a foundation for mentoring graduate students to be mentors, encouraging students to gain experience in areas that are crucial to their future success as academic staff, mentoring less-experienced students in both the academic research process and in project management responsibilities.

This course demonstrates the use of robotics competitions to provide a framework for mentoring students in the three phases of the academic research process (Figure 1). First, reviewing and evaluating past and related work and identifying an open research problem. Second, defining, validating and implementing a novel solution to the identified research problem and writing proposals for funding and travel. Third, evaluating the final solution and presenting this research through formal presentations and publications.

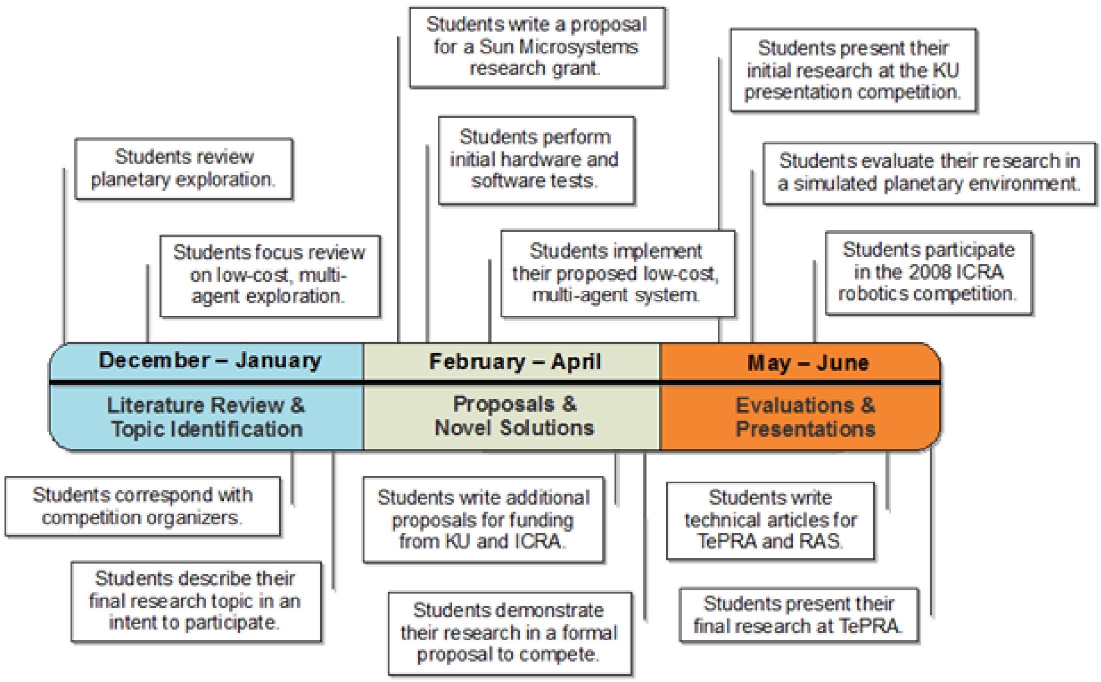

Figure 1: A timeline of the students' primary research activities during the three stages of the course.

Literature review and topic identification: The students began this stage by reviewing a broad field of research in planetary exploration, including multi-agent exploration, localisation and mapping. They identified autonomous multi-agent systems for exploration in potentially dangerous environments as an open area of research. The students next performed a comprehensive evaluation of related work in low-cost, multi-agent robotics and simultaneous localisation and mapping (SLAM). They completed this stage by submitting an intent to participate in the ICRA.

Proposals and novel solutions: The students began this stage by defining and validating a proposed solution to low-cost, autonomous multi-agent exploration through a series of hardware and software tests. They performed hardware integration tests for each component of their system, including the Gumstix Verdex XL6P motherboard [23], which was tested as the primary controller for navigation, planning, communication, and SLAM, the Java SunSPOT [24], which was used as the global pose controller for integrating position and orientation updates from SLAM, odometry, and a 3-axis Sparkfun gyroscope system [25], and the CMUcam3 colour camera [26], which was tested as the vision processing controller for identifying robots or other unique features in the environment (Figure 2a). The students performed software performance tests for a novel implementation of Distributed Particle SLAM (DP-SLAM) [27], using the limited sensing of the short-range Sharp IR sensors [28] and the limited processing of the Gumstix motherboard.

After validating the design, the students completed the implementation of their multi-agent system based on a 3-layer hybrid architecture for controlling navigation, planning and coordination [29]. This architecture includes a reactive control layer that responds directly to sensor input, a deliberative control layer that maintains and encourages long-term goals and a coordination layer that integrates the behaviours of the reactive and deliberative layers.

To simplify the complex message passing that was required both within and between the hardware components of this control architecture, from sensor input and motor control to navigation and mapping, the students implemented all intra-system and inter-system communication according to the Joint Architecture for Unmanned Systems [30] component-based message passing system (Figure 2b).

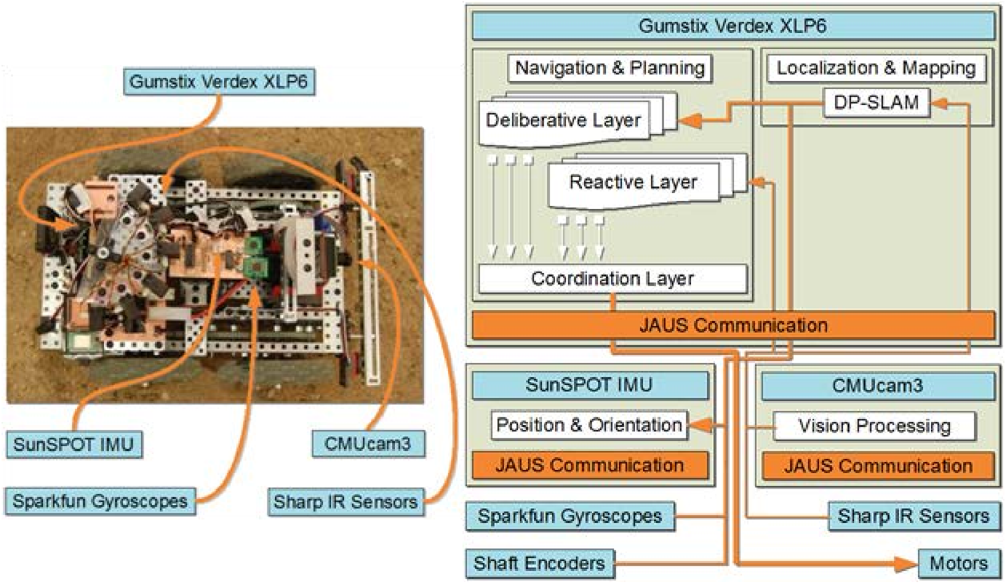

Figure 2: a) The students performed hardware integration tests for the major components of their system; b) The students implemented a 3-layer hybrid architecture for controlling navigation, planning and coordination.

Evaluation and presentation: The students began this stage by evaluating their system in a custom-built 5 m x 5 m simulated planetary environment composed of an unstructured sand and gravel terrain and obstacles, such as hills, cliffs and rocks (Figure 3a). They first tested a single prototype of their system, collecting and evaluating both raw and processed data from the prototype's exploration of the environment, including the system's raw odometry and IR sensors (Figure 3b), as well as the DP-SLAM algorithm's integration of these data to localise the robot accurately and construct a metric representation of the environment (Figure 3c).

The students completed the evaluation of their system by testing multi-agent coordination, collecting and evaluating data from both the independent systems, as well as from the final merged maps of the environment. They demonstrated the viability of the system for both coordinating multiple low-cost robots and for using efficient, low-cost sensing and processing for exploration and mapping.

The students organised and presented their research for a variety of audiences and venues, from a broad for a general audience at the 2008 KU Graduate Engineering Research Presentation Competition, to a demonstration of the multi-agent system at the 2008 ICRA competition and a technical presentation at the ICRA conference workshop and the 2008 IEEE International Conference on Technologies for Practical Robot Applications. The students completed this stage by publishing their research [31][32].

While past approaches to including robotics competitions in a graduate-level classroom have shifted the burden of team leadership and project management to a professor, this has limited the responsibilities of the students. This course provided the seasoned graduate students with the opportunity to gain experience in mentoring less experienced students in both the academic research process and in project management responsibilities. These included guiding them through each phase of the research process and collaborating with them to prepare proposals, publications, and presentations, and organising and leading them through the implementation of the proposed solution and managing the time, cost and scope of a real-world project.

The senior graduate students mentored the junior students in time management. Because the course was only one semester long, time management was critical to the project's success. The senior students, along with the academic staff, were responsible for maintaining the project timeline, milestones and deadlines. Throughout the research process, the senior students led weekly meetings, mentoring the junior students in assigning tasks and deadlines, evaluating progress and maintaining a project schedule. The senior students mentored the junior students in cost management. Robotics competitions provide the framework for writing and maintaining the budget of a significant project, and senior students were responsible for managing the necessary hardware and travel expenses of the robotics competition.

The senior students learned fiscal responsibility while mentoring the junior students in maintaining a project budget, including identifying hardware requirements and purchasing equipment within the constraints of the budget. The senior students also mentored the junior students in identifying potential funding opportunities and writing proposals for equipment and travel funding. The senior students mentored the junior students in managing the scope of a project. Because the competition was organised into a series of open-ended challenges, the students were required to identify which challenges to participate in, what goals to focus on and how these goals would be achieved. The senior students mentored the junior students in organising the team and managing resources to complete the development of the project. Throughout the course, the senior students demonstrated both the Agile [33] and Rapid Application Development (RAD) [34] processes, mentoring the junior students in assessing the risks of a project, managing changes and minimising lost functionality and revisions to the scope of the project.

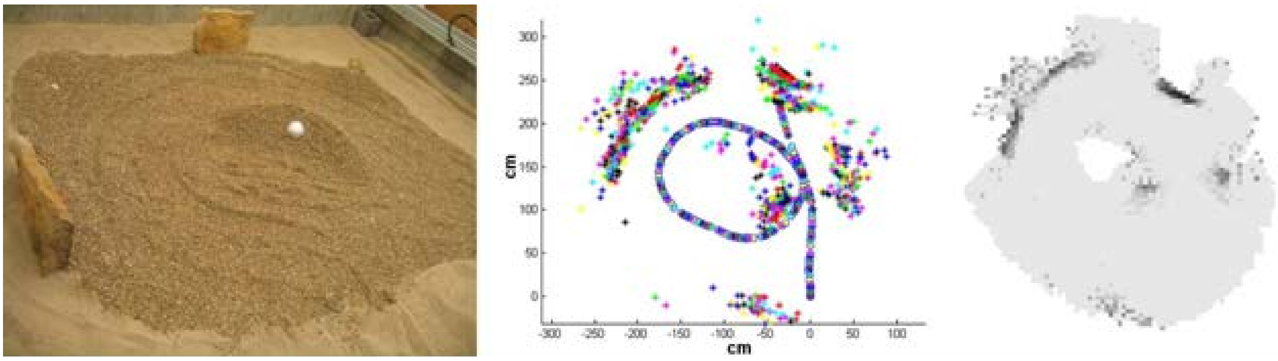

Figure 3: a) A simulated planetary environment for evaluating the student's multi-agent exploration and mapping system; b) An example of data collected while testing in this environment. The robot’s path is marked by a series of circles, starting at the bottom and ending at the top. Different shades of range data, marked with stars (*), correspond to full IR scans; c) A DP-SLAM map corresponding to the test run after integrating raw odometry and IR sensors. Darker shades indicate obstacles with a higher confidence.

ASSESSMENT

The proposed course presents a new method for evaluating graduate-level educational goals in computer science and engineering directly within the framework of a robotics competition. Because the course was led by students, facilitated by academic staff, and required a significant project to be completed within the constraints of a one-semester course, the mentorship goals of this course can be evaluated directly within the results of the students' progress. The presented results are based on one course, and although it would be beneficial to apply the approach to a few more courses, that would require several years. Instead, the results after one course are positive enough to illustrate the effectiveness of the proposed approach.

In the first stage, the competition provided the framework to assess the students' literature review and topic identification. The students corresponded with the competition organisers to ensure that an appropriate research topic had been chosen and that the competition would include challenges to showcase this research. This provided an external review of the students' progress early in the course, and allowed experts in the field to verify the strength and appropriateness of the chosen research topic. The faculty used the feedback from the competition organisers to validate the students' progress in identifying an open research problem. The faculty verified the successful completion of this stage through the competition's approval of the students' research topic. In the second stage, the competition provided the framework to assess the students' proposed solution to the identified research problem as well as their initial implementation. The assessment was provided through a series of funding proposals. The faculty used this external review to provide feedback on the proposed solution. The students were awarded four Java SunSPOT development kits from Sun Microsystems, as well as travel funding from the University of Kansas and both the ICRA conference and competition committees. These awards were competitive, and winning them meant that students could illustrate the benefits of their proposed approach, validating the overall approach.

The assessment of the students' initial implementation was provided through their formal proposal to participate in the ICRA competition. The faculty verified the successful completion of this stage when the competition organisers accepted the team to participate in the 2008 ICRA robotics competition (Figure 4). In the third stage, the competition provided the framework to assess the students' final solution and their evaluation of the research. The students verified the success of their research through the competition, during which the students won the *Onto the Surface* and *Map the Environment* challenges. Details on the mapping can be found in [35]. During the competition, the students demonstrated the redundancy of their low-cost, multi-agent system when the system recovered from the failure of one robot to map the environment successfully with the remaining robots. The faculty used the feedback from the competition judges to validate the students' final solution, taking advantage of the judges' assessment of the students' solution, as well as the judges' comparison of the students' solution to the other entries.

The assessment of the students' evaluation of their research was provided through the content and feedback of the students' presentations and peer-reviewed publications. Using manuscripts submitted for review, the faculty were able once again to take advantage of an external review for the final verification of the students' research [25][31]. In addition to the competition-based assessments, the feedback from the students was very positive. The students enjoyed the course and were challenged by the competition.

The students' participation and success in the ICRA robotics competition has been featured in both international [36] and local press [37], and the added exposure from external funding, journal publications and conference presentations has benefited the students in initiating new research opportunities, including an international research partnership on limited sensing and processing robotics with the National Institute of Advanced Industrial Science and Technology in Japan. The end of the course evaluations by the students included positive comments on the course, the faculty, and the overall experience. The only issue that the students raised was the amount of time that they had to dedicate to the course outside the class time to work on the project. They estimated that this course took twice as much as other three credit hour classes in terms of required time.

Figure 4: The students demonstrated their research at the 2008 ICRA robotics competition.

CONCLUSION

This course has demonstrated a new method for introducing robotics for education into a graduate-level curriculum by organising and assessing a course directly within the framework of a robotics competition. This course has illustrated how robotics competitions can encourage research at the graduate level by focusing the course on educational goals that are appropriate for the intellectual level of graduate students.

Through the results of the students' research and the feedback from their presentations and publications, the course has been shown to be effective for both mentoring students in the academic research process and for mentoring students to be themselves mentors to other graduate students. The future work involves applying this methodology to a large class, potentially consisting of students from various majors, in order to be able to form multi-disciplinary teams and evaluate their effectiveness.

REFERENCES

1. Miller, D.P., Nourbakhsh, I.R. and Siegwart, R., *Robotics for Education*. In: Siciliano, B. and Khatib, O. (Eds), Springer Handbook of Robotics, Berlin: Springer Verlag, 911-920 (2008).
2. Nourbakhsh, I.R., Kunz, C. and Willeke, T., The Mobot museum robot installations: a five year experiment. *Proc. IEEE/RSJ Inter. Conf. on Intelligent Robots and Systems*, 3636-3641 (2003).
3. Cooper, M., Keating, D., Harwin, W. and Dautenhahn, K., Robots in the classroom - tools for accessible education. In: Bühler, C. and Knops, H. (Eds), *Proc. 5th European Conf. for the Advancement of Assistive Technol.*, Düsseldorf, Germany: IOS Press, 448-452 (1999).

4. Schumacher, J., Welch, D. and Raymod, D., Teaching introductory programming, problem solving and information technology with robots at West Point. *Proc. 31st Frontiers in Educ. Conf.*, 2, (2001).
5. Murphy, R.R., Teaching image computation in an upper level elective on robotics. *Inter. J. of Pattern Recognition and Artificial Intelligence*, 12, **8**, 1081-1094 (1998).
6. Doulgeri, Z. and Matiakis, T., A web telerobotics system to teach industrial robot path planning and control. *IEEE Transactions on Educ.*, 49, **2**, 263-270 (2006).
7. Ruiz-del-Solar, J. and Avilés, R., Robotics courses for children as a motivation tool: the Chilean experience. *IEEE Transactions on Educ.*, 4, **4**, 474-480 (2004).
8. Pomalaza-Ráez, C.A. and Groff, B., Retention 101: where robots go... students follow. *J. of Engng. Educ.*, 92, **1**, 85-90 (2003).
9. Pack, D.J., Avanzato, R., Ahlgren, D.J. and Verner, I.M., Fire-fighting mobile robotics and interdisciplinary design-comparative perspectives. *IEEE Transactions on Educ.*, 47, **3**, 369-376 (2004).
10. Verner, I.M. and Ahlgren, D.J., Fire-fighting robot contest: interdisciplinary design curricula in college and high school. *J. of Engng Educ.*, 91, **3**, 355-359 (2002).
11. Malec, J., Some thoughts on robotics for education. *Proc. 2001 AAAI Spring Symposium on Robotics and Education*, Stanford University (2001).
12. Gregson, P.H. and Little, T.A., Using contests to teach design to EE juniors. *IEEE Transactions on Educ.*, 42, 229-232 (1999).
13. Verner, I.M. and Ahlgren, D.J., Robot contest as a laboratory for experiential engineering education. *J. on Educational Resources in Computing*, 4, **2**, 1-15 (2004).
14. Verner, I.M., Ahlgren, D.J. and Miller, D.P., Robotics Olympiads: a new means to integrate theory and practice in robotics. *Computers in Educ. J.*, 17, **4**, 11-21 (2007).
15. Murphy, R.R., Using robot competitions in the classroom to promote intellectual development. *AI Magazine*, 21, **1**, 77-99 (2000).
16. Pavelich, M.J. and Moore, W., Measuring maturing rates of engineering students using the Perry model. *Proc. 23rd Frontiers in Educ. Conf.*, 451-455 (1993).
17. Weinberg, J.B., Pettibone, J.C., Thomas, S.L., Stephen, M.L. and Stein, C., The impact of robot projects on girls' attitudes toward science and engineering. *Proc. Robotics Science and Systems (RSS) Workshop on Research in Robots for Educ.*, Atlanta, Georgia (2007).
18. Ahlgren, D. and Verner, I.M., Building self-efficacy in robotics education. *Proc. ASEE Annual Conf.*, Honolulu, Hawaii (2007).
19. Siegwart, R., Grasping the interdisciplinarity of mechatronics. *IEEE Robotics and Automation Magazine*, 8, **2**, 27-34 (2001).
20. Balch, T. and Yanco, H., Ten years of the AAAI mobile robot competition and exhibition: looking back and to the future. *AI Magazine*, 23, **1**, 13-22 (2002).
21. ICRA, The ICRA Robot Challenge, 1 January 2012, http://icra.wustl.edu.
22. NASA, Mars Exploration Rover Mission: Home, 1 May 2009, http://marsrover.nasa.gov/home/index.html.
23. Gumstix, Motherboards, 15 November 2011, http://www.gumstix.com/platforms.html.
24. Sun Microsystems, SunSpotWorld - Home of Project Sun SPOT, 1 February 2008, http://www.sunspotworld.com.
25. SparkFun Electronics, Sensors: IMU/Gyros, 1 February 2008, http://www.sparkfun.com/commerce/categories.php?c=85.
26. Seattle Robotics, 1 February 2008, CMUcam3. http://seattlerobotics.com/cmucam3.htm.
27. Eliazar, A. and Parr, R., DP-SLAM: Fast, Robust Simultaneous Localization and Mapping without predetermined landmarks. *Proc. 18th Inter. Joint Conf. on Artificial Intelligence*, 1135-1142 (2003).
28. Acroname Robotics, Sharp GP2Y0A02YK IR Sensor, 1 February 2008, http://acroname.com/robotics/parts/R144-GP2Y0A02YK.html.
29. Burguera, A., Gonzalez, Y. and Oliver, G., A solution for integrating map building and self localization strategies in mobile robotics. *Inter. J. of Intelligent Systems*, 20, **5**, 499-521 (2005).
30. JAUS, The Joint Architecture for Unmanned Systems, Reference Architecture Specification Version 3.3, 1 February 2008, http://www.jauswg.org/.
31. Gifford, C.M., Webb, R., Bley, J., Leung, D., Calnon, M., Makarewicz, J., Banz, B. and Agah, A., A novel low-cost, limited-resource approach to autonomous multi-robot exploration and mapping. *Robotics and Autonomous Systems*, 58, **2**, 186-202 (2010).
32. Gifford, C.M., Webb, R., Bley, J., Leung, D., Calnon, M., Makarewicz, J., Banz, B. and Agah, A. Low-cost multi-robot exploration and mapping. *Proc. IEEE Inter. Conf. on Technologies for Practical Robot Applications*, 74-79 (2008).
33. Martin. R.C., *Agile Software Development, Principles, Patterns, and Practices*. Upper Saddle River, N.J.: Prentice Hall (2002).
34. Martin, J., *Rapid Application Development*. Upper Saddle River, N.J.: Prentice Hall (1992).
35. KU ICRA, Challenge Team Multi-Media, 1 May 2010, http://people.eecs.ku.edu/~icra/public/media.
36. BBC World Service Radio, Science in Action: ICRA 2008 Robot Challenge, 30 May (2008).
37. Ad Astra Kansas News, KU Students win honors at international robotics conference, 9 September 2008, http://www.adastra-ks.org/news/2008/ku.shtml.

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