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- M. S. Wald** 689 Editorial
- G. T. McKee** 690–691 Guest Editorial
- G. T. McKee** 692–701 The Maturing Discipline of Robotics
- The nature of the robotics discipline is changing. In turn the traditional engineering-based degree programmes that have promoted robotics as an application of engineering principles need to be supplemented with robot-centred degree programmes that reflect the diverse character of robotics, the diverse interests of students, and the diverse multi-disciplinary contributions to the robotics discipline. In this paper the nature of the change that robotics has undergone in recent years is described. An outline of the subject material of robotics, comprising robotics science and robotics engineering, is discussed. The teaching of robotics degree programmes in the past has been hampered by the expense required to install and maintain a robotics teaching laboratory. Availability of online robot systems and numerous robot kits has changed this situation to some extent. However, the paper concludes that there is still a need for good educational toolkits for teaching robotics at a first degree level.*
- Keywords:** robotics education; robotics body of knowledge; undergraduate robotics programmes; interdisciplinary robotics programmes; robotics toolkits; robotics science and engineering
- A. R. S. Castellanos, L. H. Santana, E. Rubio, I. S. Ching and R. A. Santonja** 702–710 Virtual and Remote Laboratory for Robot Manipulator Control Study
- This paper presents a distance laboratory that enables the remote testing of coupled and non-coupled control algorithms in robot manipulators. The developed laboratory allows the users to use predefined controllers or design their own controllers using the Matlab-Simulink environment. The targeted controllers (designed by the users) can use S-Functions, which they can create themselves using C language; this functionality permits the creation and testing of complex controllers in an easy and fast way. This system uses Matlab-Simulink for practice processing and the Real Time Workshop Toolbox (RTW) such as real time kernel. The laboratory allows simple integration of new robots for control experiments. At present it has a robot manipulator with five degrees of freedom in Cuba, which uses two degrees of freedom for carrying out experiments. The laboratory has been used since year 2003 in identification and control theory in undergraduate courses in Universidad Central 'Marta Abreu' de las Villas and Universidad de Cienfuegos in Cuba, and in robotics and advanced control postgraduate courses in Instituto Tecnológico de Minatitlán in Mexico.*
- Keywords:** distance education; virtual laboratory; remote laboratory; robot control; remote control
- E. Cejka, C. Rogers and M. Portsmore** 711–722 Kindergarten Robotics: Using Robotics to Motivate Math, Science, and Engineering Literacy in Elementary School
- Robotics naturally lends itself to teaching math, science, technology and engineering in the K–12 classroom. LEGO Mindstorms makes it easy for students even in kindergarten to design and build their own robotic creations. However, the key to bringing engineering into K–12 through robotics is educating teachers on the content, how to use the materials, and how open-ended design problems can be effective in the classroom. This paper details the Tufts University Center for Engineering Educational Outreach's theoretical framework, motivations, and efforts involved in bringing engineering via LEGO robotics into every kindergarten through fifth-grade classroom in one school through the Systemic School Change in Engineering Project. Preliminary results and recommendations are presented.*
- Keywords:** elementary schools; systemic change; professional development; educational technology; LEGO robotics
- B. E. Bishop, J. A. Piepmeier, G. Piper and K. A. Knowles** 723–731 Low-Cost Robotic Laboratory Exercises and Projects
- In commonly used robotic texts, the introductory chapter defines robotics and explores the role of robotics in industry and society. This is followed by transformation matrices and forward and inverse kinematics. Homework, quizzes, and exams are used to reinforce lecture material. For some students, three-dimensional concepts and mathematical tools are obvious, but for others it is impossible to relate two-dimensional pictures (from a text or the board) to a three-dimensional reality. Furthermore, besides a poor grade, there is no immediate feedback on the consequences of incorrectly assigning coordinate frames or improperly deriving the inverse kinematics of a manipulator. This paper discusses laboratory assignments utilizing inexpensive hardware such as remote-controlled (RC) servomotors, ROBIX[®] RCS-6 kits, and inexpensive vision systems such as CMU-cams and webcams. It is shown that low-cost systems are suitable for both reinforcing fundamental robotic concepts such as inverse kinematics and facilitating independent student research.*
- A. Khamis, F. Rodríguez, R. Barber and M. A. Salichs** 732–742 An Approach for Building Innovative Educational Environments for Mobile Robotics
- This paper presents an approach to building innovative environments for mobile robotics education. The proposed approach can be used to create new courses or to update existing courses that are currently taught in a traditional way. It has been successfully used to build an innovative teaching environment in the field of indoor mobile robotics at Carlos III University of Madrid. A postgraduate course on intelligent autonomous robots has also been updated based on this approach.*
- Keywords:** tele-education; mobile robotics; remote laboratory; remote experimentation
- J. Noguez and L. Sucar** 744–757 Intelligent Virtual Laboratory and Project-Oriented Learning for Teaching Mobile Robotics
- We have combined collaborative didactic techniques, virtual laboratories and intelligent tutors to improve the process of learning mobile robotics. The students learn the basic concepts in mobile robotics, first by experimenting in a virtual laboratory and later by building a small mobile robot for a competition. The course is based on the project-oriented learning (POL) didactic strategy. Throughout the*

course the students design, build and program a small mobile robot to participate in student competitions. Here we present an evaluation of the virtual lab and of the tutor, and of the course in general.

I. Verner and E. Korchnoy 758–765 Experiential Learning through Designing Robots and Motion Behaviors: A Tiered Approach

This paper considers the Teaching Methods of Design and Manufacturing course, in which engineering students develop various robots and teach robotics to school pupils. The students are involved in the experiential learning process which integrates designing and producing working prototypes with studying engineering subjects and project guidance methods. The robots developed in the course and the experiments directed to their optimization through review–revise–prototyping cycles are considered. The features of rapid prototyping using construction kits and the value of practice in teaching robotics are analyzed.

Keywords: robotics; experiential learning; teacher education; design projects; competitions

F. Torres, F. A. Candelas, S. T. Puente, J. Pomares, P. Gil and F. G. Ortiz 766–776 Experiences with Virtual Environment and Remote Laboratory for Teaching and Learning Robotics at the University of Alicante

This paper begins with a description on the state of the art of robotics education in Spain. We then present our virtual environment and remote laboratory, whose principal component is RoboLab, a system that allows the student to interact with simulated and real robots through the Internet. Afterwards, we describe the main aspects of our Robotics courses at the University of Alicante, as well as the practical exercises carried out by students using the virtual laboratory. We then present an analysis of our experience of using the virtual and remote laboratory and give our conclusions, in which we analyze the advantages and disadvantages of using our virtual environment and remote laboratory to teach Robotics.

Keywords: virtual laboratory; remote laboratory; e-learning; robotics

I. Nourbakhsh, E. Hamner, E. Ayoob, E. Porter, B. Dunlavey, D. Bernstein, K. Crowley, M. Lotter, S. Shelly T. Hsiu and D. Clancy 777–791 The Personal Exploration Rover: Educational Assessment Of A Robotic Exhibit For Informal Learning Venues

Robotics brings together learning across mechanism, computation and interaction using the compelling model of real-time interaction with physically instantiated intelligent devices. The project described here is the third stage of the Personal Rover Project, which aims to produce technology, curriculum and evaluation techniques for use with after-school, out-of-school and informal learning environments mediated by robotics. Our most recent work has resulted in the Personal Exploration Rover (PER), whose goal is to create and evaluate a robot interaction that will educate members of the general public in an informal learning environment and capitalize on the current enthusiasm and excitement produced by NASA's Mars Exploration Rovers (MERs). We have two specific goals: teaching about the role of rovers as tools for scientific exploration and teaching about the importance of robot autonomy. To this effect we have designed an interactive, robotic museum exhibit that has been deployed at five locations across the United States, including the San Francisco Exploratorium and the Smithsonian National Air and Space Museum. Here we introduce the robot hardware and software designed for this task and the exhibits developed, then detail the educational assessment methodology and results, which encompass exhibit impact on museum visitors at two installation sites.

V. Wilczynski and W. Flowers 792–803 FIRST Robotics Competition: University Curriculum Applications of Mobile Robots

The FIRST (For Inspiration and Recognition of Science and Technology) Robotics Competition challenges teams to design, build and compete tele-operated mobile robots. As a mentorship program to interest high school youth in engineering, science and technology, the FIRST Robotics Competition partners high school students with volunteers from the education, engineering, business and civic communities. In 2005 nearly 1000 teams from seven countries competed in the FIRST Robotics Competition. Many universities participate in FIRST as competition hosts, student mentors and team sponsors. This paper examines interactions associated with the FIRST Robotics Competition. Four course models are presented to illustrate a developmental sequence for undergraduate courses centered on the FIRST Robotics Competition. Also, additional examples of FIRST Robotics Competition related labs and lecture instructions are presented.

Z. Qu and X. Wu 804–814 A New Curriculum on Planning and Cooperative Control of Autonomous Mobile Robots

This paper presents the robotics curriculum that was developed and is currently offered in the Department of Electrical and Computer Engineering (ECE) at the University of Central Florida (UCF). The curriculum retains many features of typical robotics curricula, such as being multidisciplinary, hands-on, and integrated. It also has several unique features, including a contemporary focus and a means of updating its contents and teaching a variety of topics. It represents one way of developing a curriculum on autonomous and intelligent robotic systems. As measured by the reactions from students and local industry, its implementation has been successful.

Keywords: curriculum development; course offerings; laboratory components; autonomous vehicles; intelligent systems

H. Temelta, M. Gokasan and S. Bogosyan 815–828 Hardware in the Loop Robot Simulators for On-site and Remote Education in Robotics

In this study, a new approach in Hardware-In-the-Loop Simulation (HILS) is introduced as an education tool in robotics, mechatronics and control. The paper discusses the development and utilization of HILS specifically in the instruction of control and design aspects of on-site and remote robotics courses. A HIL simulator differs from computer simulation as it involves actual hardware and is not limited with the software representation of the system. The HIL architecture proposed in this study is a novel contribution to robotics education and is different from previous HIL structures for robotics, in that the developed test-bed involves the actual joint actuator and can be programmed to reflect actual dynamics affecting that particular joint in the given robotic structure. Two motors driven by high performance DSP boards are used for this purpose; one representing the joint actuator and the other used for the generation of all the torque components affecting that joint for the robot system in consideration. Thus, it is possible to evaluate the overall performance of the robot and its end-effector by combining the data from each simulated joint-associated dynamics pair. The wide range of kinematic configurations thus offered by the simple structure of HILS makes them an attractive, cost-effective solution for the problem of limited repertoire in robotics labs, giving the students the opportunity to experiment with 'open architecture robots' that are essential for a thorough education in robot control, but on the other hand are quite rare and may not be available in an average lab environment. Additionally, similar to its use in the robotics lab applications presented in this study, HILS can provide a comprehensive test environment prior to the implementation of new control strategies on the actual system, thereby ensuring the safe use and longevity of high-cost robots in on-site/remote labs. The proposed HIL architecture is combined with a client/server software configuration to allow students access to the test-bed. The results obtained from the remote control of a two-degrees-of-freedom planar arm presented as a case study have motivated the utilization of the system as an efficient education and research tool for on-site and remote robotics laboratories.

P. K. McKinley, B. H. C. Cheng and J. Weng 829–838 Integrating Multimedia Technology into the Undergraduate Curriculum

Given the ubiquity of multimedia technology, it is important that Computer Science students not only learn the basics of multimedia design, but also gain hands-on experience with applications of the technology. This paper describes the integration of multimedia concepts and tools into a Computer Science curriculum. An NSF-sponsored Multimedia Laboratory was established and used to support three senior-level courses: software engineering, computer graphics, and computer networks. Curriculum development activities, laboratory exercises, and the role of course projects are described.

S. Maurice and S. Lissel 839–848 Evaluating Online Testing Technology

This study reports results on how design aspects of technology and perceptions of students towards online testing technology affect the learning and preparation process of students. It follows a previous study conducted by Maurice and Day who found that students generally disliked online testing technology due mainly to design and performance of the technology. Using the recommendations from the previous study, the authors redesigned the online testing technology. The purpose of this study is to evaluate the redesigned online technology and show whether the recommendations made by Maurice and Day had a positive impact on students with respect to access to and use of the new testing tool. Using data from a survey completed by 157 university students in an undergraduate engineering course, we present a summary of their feedback on whether the redesigned online testing technology was an effective tool in helping them learn the course material and a good preparation for exams. The results in this paper are compared with the results in the previous paper. Our results show that the changes made to the online testing technology, as recommended in the previous paper, did have a positive impact on the students. Specifically, student feedback was much 'nicer' than in the previous study. Our results validate the recommendations in the previous paper—at least in the present sample. We also present an instructor's view and experience with the new online testing technology. The instructor's experience with the new online testing technology was also positive.

I. Mougharbel, A. El Hajj, H. Artail and C. Riman 849–857 Remote Lab Experiments Models: A Comparative Study

Remote Laboratory Experimentation (RLE) is a technique used in modern engineering laboratories to help academic researchers and students perform laboratory experiments remotely through the Internet. Many RLE implementations are available with different characteristics. In this work, some recent RLE implementations models are analyzed, the services provided by each model are discussed, and these models are compared and evaluated.

H. Drury, T. Langrish and P. O'Carroll 858–867 Online Approach to Teaching Report Writing in Chemical Engineering: Implementation and Evaluation

Although interactive computer-based learning approaches are common in engineering education, this approach has rarely been used to teach writing skills. This paper reports on an interactive online program that aims to teach report writing in chemical engineering. The development of the program is discussed together with its integration into the curriculum. Finally, evaluation approaches and analysis are presented. Although the overall evaluation was positive, questions are raised about how to improve student confidence in writing, help students transfer their learning to other writing contexts and use their writing to deepen their knowledge of engineering subject matter.

Keywords: report writing; communication studies; chemical engineering; computer-based learning; laboratory feedback

C.-Y. Lam and F. Koh 868–875 A Partial Differential Equation Solver for the Classroom

This paper presents a solver for partial differential equations that was developed in Microsoft Excel. The solver consists of selected finite-difference numerical methods for the three types of partial differential equations: namely the elliptic, parabolic and hyperbolic equations. The partial differential equations and the finite-difference methods implemented are commonly used in classroom teaching. Regular cell arrangement in worksheets represents the finite-difference grid. The computational procedures were translated into Visual Basic for Application code to automate the methods. The solver can handle problems with Dirichlet and Neumann boundary conditions. A graphical user interface accepts problem parameters while worksheets and charts display the numerical solutions. The solver requires minimal spreadsheet knowledge from the users. Various numerical experiments such as divergence and stability testing can be performed easily. These allow users to concentrate on the numerical aspects of their problems, which enhances the learning of the numerical methods.

Keywords: partial differential equations; spreadsheet; differential equation solver; numerical method

W. Lee, P.-C. Lin and C.-K. Tseng 876–881 The CD Lens for Optical Engineering

Compact disks as a device for the teaching of optics have uses other than traditional diffraction experiments. Like a Fresnel zone plate that can focus light and form images of distant objects, the circular grating-like structure of a compact disk (CD) renders itself a chromatic lens. This paper suggests an interesting experimental activity that can be easily reproduced for early physics classes. The optical converging nature and chromatic characteristics of focal lengths of the CD lens are experimentally presented and theoretically interpreted.

R. C. Woods 882–885 Estimation of Light Speed using PC/Windows Networked Computers

A recent proposal for a classroom experiment to estimate the speed of light using a networked computer relies upon some special hardware and Linux machines able to measure the time-of-flight to the nearest microsecond. At first sight, ordinary PCs running Windows appear not to be capable of this application because their software time-of-flight measurement is limited to the nearest millisecond. This paper shows how an ordinary networked PC/Windows machine may be used for an equivalent time-of-flight rough estimation of the speed of light having literally zero cost if one networked computer is already available. This allows remote students to estimate the speed of light with only consumer-grade computers and no specialized hardware available. Feedback from students has been highly favorable.

R. J. Stanley, S. E. Watkins, R. H. Moss and A. Gopal 886–895 Traffic Monitoring Using a Three-Dimensional Object Tracking Approach

An orthographic projections-based algorithm was investigated for the traffic monitoring application of tracking a truck moving across a bridge through a sequence of video image frames. The two-dimensional position of a specific marker on the truck for each video frame is found using color thresholding-based segmentation. A coordinate transformation process provides the real-world, three-dimensional location of the marker position for tracking the truck. The procedure is experimentally illustrated with a field bridge. This paper presents the experimental bridge setup, the marker identification technique, the orthographic coordinate transformation algorithm, and web-accessible laboratory exercises developed for image processing and related curricula.

Network management and the application of the different components have become an important part of networks in industry. Therefore, it has become important to teach network management to potential employees of companies which have come to rely on large networks. One of the more important network management protocols is known as Simple Network Management Protocol. This paper presents, in some detail, a new development of an SNMP laboratory for a specialisation subject in Telecommunications engineering based on this protocol. Other aspects of this laboratory include three other types of network management applications: Nagios, TKINED and a remote monitor known as RMON probe. Encryption and decryption are also introduced and studied in depth for security aspects of network management. The students are required to complete the laboratory tasks in six weeks and are required to submit reports based on this work demonstrated in the laboratory.

Keywords: SNMP; Nagios; TKINED; RMON; Network; Security; DES