This is the ACCEPTED VERSION of the manuscript published in in IEEE Transactions on Education, vol. 54, no. 1, pp. 41-47, Feb. 2011, doi: 10.1109/TE.2010.2043359

Using NXT LEGO Mobile Robots with LabVIEW for Undergraduate Courses on Mechatronics

Jesús M. Gómez-de-Gabriel, Anthony Mandow, *Member, IEEE*,
Jesús Fernández-Lozano, and Alfonso García-Cerezo, *Member, IEEE*

Abstract

The paper proposes lab work and student competitions based on the LEGO NXT Mindstorms kits and standard LabVIEW. The goal of this combination is to stimulate design and experimentation with real hardware and representative software in courses where mobile robotics is adopted as a motivating platform to introduce mechatronics competencies. Basic LabVIEW examples are proposed for three case study laboratory practices. These are implemented with the NXT Toolkit and the NXT Direct Command programming libraries for stand-alone and remote execution, respectively. The application of this instructional material has been tested in two different experiences with senior undergraduate engineering students. A description of the courses as well as an assessment of student results are also included.

Index Terms

Engineering education, LabVIEW, Lego Mindstorms NXT, mechatronics, mobile robots, project-based learning, robot programming.

I. Introduction

Mechatronics is a philosophy that synergistically fuses different engineering disciplines to enhance the design of technological products and manufacturing processes. These include mechanics, electronics, control, systems design, embedded computing, and intelligent systems. The interest gained by this area has increased the demand on engineers with interdisciplinary competencies. As pointed out in [1], mechatronics ”focuses on the process of learning linked with actions rather than teaching, and the learning process is

The authors are with the Dpto. Ingeniería de Sistemas y Automática, Universidad de Málaga, 29071 Málaga, Spain (e-mail: jesus.gomez@isa.uma.es; amandow@uma.es; jesus.fernandez@isa.uma.es; ajgarcia@uma.es).

The 2^{nd} Summer Course on Mechatronics was partially funded by the University of Málaga and the Technical University of Dresden. Additional funding was obtained from TEP-1379 and TEP-375 (Junta de Andalucía, Spain).

directly coupled with thinking.” Thus, mechatronics is bound to play a crucial role in engineering education as a unifying, interdisciplinary, and intelligent science paradigm.

Autonomous mobile robots have been widely adopted as motivating platform for introducing mechatronics at all educational levels. Experiences have been reported with hobby kits [2], small-scale commercial vehicles [3], and toy-based robots by Meccano [4] and LEGO [5], [6]. The LEGO Mindstorms kit is arguably the most widely used educational platform, as it is relatively inexpensive, reusable, robust, reconfigurable, and its modules are familiar to all types of students [7]. Mindstorms have been employed to assess technological perception in preschool children [8], to introduce basic technology and problem solving in secondary school [9], [10], to teach engineering technologies to freshmen at undergraduate levels [7], [11], [12], and also for more specialized courses [13].

Programming languages provided by LEGO (i.e., RoboLab and Education NXT Software) have contributed to this wide-ranging educational use. Both are based on National Instruments LabVIEW. RoboLab was developed for the RCX programmable brick in the first generation of LEGO Mindstorms. This language was an intuitive and visual tool suitable for students with any technological background. It allowed the writing of simple programs and their downloading to the LEGO brick, but standard LabVIEW structures could not be used [5]. Alternative community-sourced graphical environments have been proposed, but generally they are not powerful enough for advanced work [6]. Thus, higher education courses have sought more general solutions, like Java [14], or ANSI C [7], by replacing the LEGO brick firmware.

The second generation of LEGO programmable bricks (NXT), with their companion entry-level Education NXT Software, was launched in 2006. NXT bricks incorporate a more powerful microcontroller as well as Bluetooth communication capabilities. These improvements have allowed that engineering programming environments can be used with unmodified LEGO units [12]. Thus, remote control functions can be programmed with MATLAB running in a host computer [12], [15]. Furthermore, NXT units directly support LabVIEW. This way, it is possible to run standard LabVIEW programs remotely, and also to upload them to the NXT brick [16].

LabVIEW is a programming environment suitable for undergraduate engineering education [17]. It offers support for data acquisition hardware, built-in libraries, multi-tasking, and simple definition of user interfaces, and is widely use in professional engineering. For these reasons, this software tool is found in university courses on mechatronics [18], electricity and electronics [19], digital signal processing [20], control [21], [22], and in remote laboratories [23]. Furthermore, it is employed in actual mechatronics/robotics applications (e.g., [24], [25], [26]).

Fig. 1. LEGO NXT mobile robot.

The paper proposes lab work and student competitions based on LabVIEW and LEGO Mindstorms NXT kits, Fig. 1. Basic mobile robot lab examples with LabVIEW solutions are discussed. These instructional materials have been developed for two teaching experiences at the University of Málaga (Spain) with senior undergraduate engineering students: the 2^{nd} Summer School on Mechatronics [16], jointly organized with the Technical University of Dresden (Germany), and a mobile robotics course offered for the Master's-level Engineering degree in Automation and Industrial Electronics.

The paper is organized as follows. After this introduction, an overview of the courses is presented in Section II. Then, Section III offers a brief description of the LEGO NXT unit and specific LabVIEW programming tools. Section IV describes simple lab work examples and proposes student competitions. Section V offers an assessment of educational results. Finally, the last sections are devoted to conclusions, acknowledgements and references.

II. Overview of the courses

The instructional material presented below was developed and tested in the frame of two teaching experiences at the University of Málaga (Spain) with senior undergraduate engineering students:

- The 2^{nd} Summer School on Mechatronics, held in 2008, which was jointly organized with the Technical University of Dresden (Germany) [16]. This was attended by 20 selected applicants from several engineering degree programs. Therefore, the learning objectives of this intensive two-week program pursued interdisciplinarity. These objectives included mobile robotics, control architectures,

TABLE I

SUMMER SCHOOL CONTENTS RELATED TO LEGO/LABVIEW

Objective	**Lab content**	**Program Model**	**Lab Hours**
Prerequisite: LabVIEW basics	LabVIEW introduction tutorial.	Generic	6
Mobile robot architectures	Introduction to LabVIEW/Lego NXT programming: Sensors reading and basic program structure.	NXT Toolkit	2
	Mobile robot control basics: Vehicle kinematics and state machines.	NXT Direct	2
Mobile robot control	Tele-operated vehicle control: User interface and advanced programming structures.	NXT Direct	2
	Autonomous mobile robot control: Line following.	NXT Toolkit	2
Competition	Line following (see Section IV-B.1).	NXT Toolkit	4
Intelligent robot control	Special sensors.	NXT Direct	2
	Fuzzy logic control.	NXT Toolkit	2
Competition	Reactive navigation (see Section IV-B.2).	NXT Toolkit	4

sensors and actuators, fuzzy logic, and project development. Lab work was related to these topics, with two competition projects (one at the end of each week). The courses that took part of the LEGO/LabVIEW experience in the 2008 Summer School are described in Table I. As a prerequisite, participants had to study a LabVIEW introduction tutorial so that they had a basic knowledge of this tool.

- A one-semester mobile robotics course offered in 2009 for the Master's-level Engineering degree in Automation and Industrial Electronics of the University of Málaga. The theoretical contents included mobile robot configurations, sensing, and deliberative and reactive navigation strategies. This course was taken by six students. The practical part of the course comprised eight supervised lab sessions, as presented in Table II. A single competition was held at the end of the course.

III. LEGO NXT AND LABVIEW

This section briefly describes the LEGO NXT hardware (particularly, Education Base Set #9797) as well as the LabVIEW software (for version 8.2.1) available for programming unmodified NXT units. The LEGO NXT brick is a battery-powered module based on a 32-bit ARM micro-controller with an LCD display, four input ports for sensors, and three input/output servo-motor ports. In addition, communication with a computer is possible through Bluetooth or USB cable. Both can be used to access NXT services

TABLE II

MOBILE ROBOTICS COURSE CONTENTS RELATED TO LEGO/LABVIEW

Objective	**Lab content**	**Program Model**	**Lab Hours**
Introduction to LabVIEW and LEGO NXT	Work with a given differential drive (DD) robot configuration.	NXT Toolkit	2
Basic programming	Obstacle avoidance with range sensor in a maze.	NXT Direct	2
Advanced programming and control	Wheel drive control. Differential drive control strategies. Achievement of straight line motion. Tuning of velocity PID based on object properties.	NXT Toolkit	2
Locomotion configurations: Construction	Wheeled and tracked configurations. Implementation of a choice configuration, different from DD.	NXT Direct / Toolkit	2
Locomotion configurations: Control	Line following with light sensor. Comparison of locomotion configurations performance. *Announcement of competition rules.*	NXT Toolkit	2
Perception	Competition robot design. Sensor arrangement. Preliminary tests.	NXT Toolkit	2
State-based control	Implementation of Finite State Automata. Competition test and debugging.	NXT Toolkit	2
Competition	Clearing an area (see Section IV-B.3).	NXT Toolkit	2

such as program downloading and monitoring. The education set includes three servo-motors and a sensor kit with two switches, an analog light sensor, a sound sensor, and a range sonar. A variety of mechanical components and pieces allow for different physical arrangements and kinematic configurations. If required, kits with additional building components, as Set #9648, are available.

The programming environment requires standard LabVIEW plus the LabVIEW Lego NXT add-on [27]. This add-on includes two different specific VI libraries that support two alternative programming modes:

- *NXT Toolkit*. Compiled programs are downloaded to the NXT brick. Nevertheless, program execution may be supervised or debugged from the computer screen though a standard LabVIEW Front Panel GUI. This GUI can include both controls, to change program signals, and indicators. This programming mode supports a subset of the standard LabVIEW features with special blocks for NXT sensors and actuators. Programming constraints include integer computation and limited memory. In any case, unlike Education NXT Software, this is standard LabVIEW, so experience from other applications can be used here, and vice versa. From an educational perspective, the NXT Toolkit mode can be more motivating for students, as the robot can actually exhibit an untethered autonomous

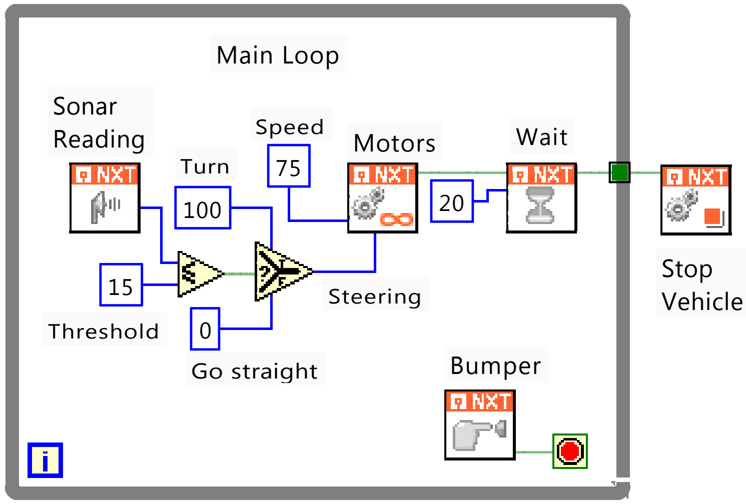


Fig. 2. LabVIEW diagram for basic control.

behavior.

- *NXT Direct Commands*. Programs are executed in the host computer with support for full LabVIEW resources. The NXT Direct Commands Library offers blocks to access NXT services such as sensor reading, motor control, file handling, and device management. These services are part of the standard NXT brick firmware. This mode is suitable for applications that require external resources like MATLAB, ActiveX components, special I/O devices like joysticks, or extra computational power and memory.

IV. Lab-work with LEGO NXT and LabVIEW

A. Instructional Material

This section proposes three basic LabVIEW implementations for lab-work with LEGO NXT kits: a basic open-loop controller and a sensor-based navigator (both in NXT Toolkit mode), and a remote control (in NXT Direct mode).

1) Basic control: A simple LabVIEW example for robot control is presented in Fig. 2. It contains five NXT Toolkit blocks. The input value to the motors controls steering and speed. Steering is based on an ultrasonic sensor block. This controller produces straight line motion unless the sonar is below a constant $15\,\mathrm{cm}$ threshold. In that case, the maximum curvature is generated. If the bumper hits an obstacle, the main *While* loop terminates and the vehicle is stopped.

2) Sensor-based navigation: This example illustrates a line-following controller using the NXT Toolkit mode (see Fig. 3). Specific NXT blocks are used to read the light and ultrasonic sensors, to synchronize differential drive outputs, and to set loop timing. The edge of a thick black line on a white floor is detected

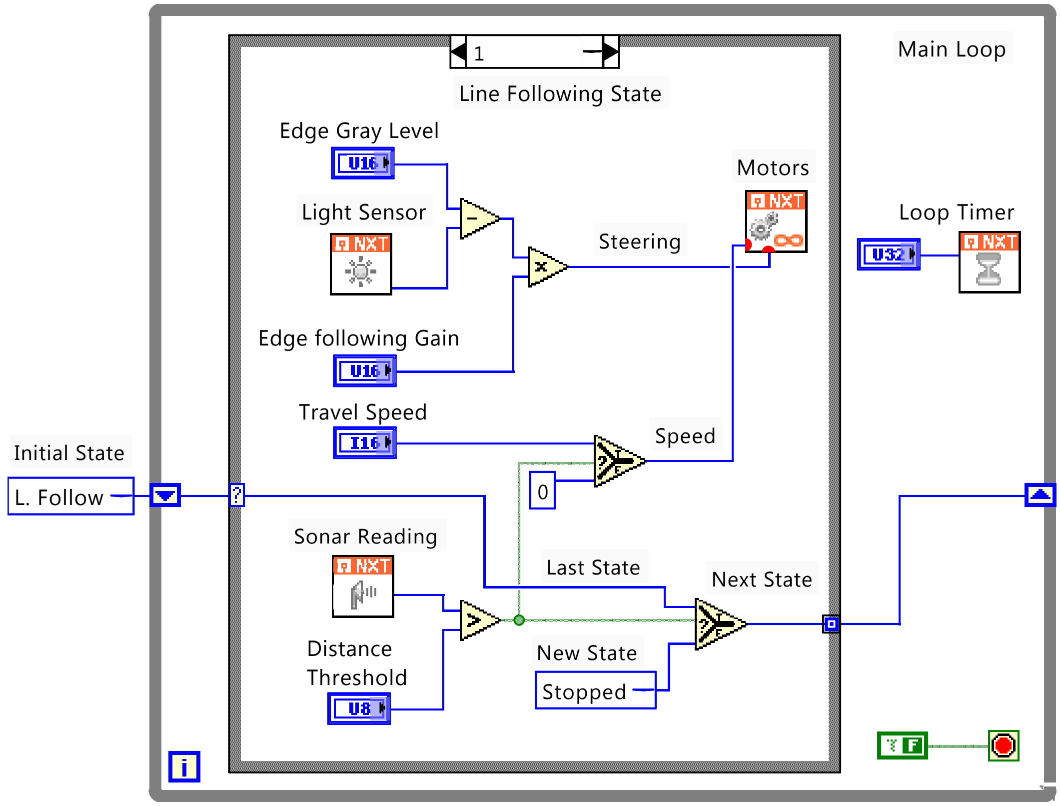


Fig. 3. LabVIEW diagram for line following with the light sensor.

as a gray level provided by the analog light sensor. This solution also implements a simple finite state machine, whose initial state is ”line following,” which is changed to a ”stopped” state (whose diagram is not shown in the figure) when a close obstacle is detected by the sonar. This state-based approach allows for more flexible behavior sequences, which the student can find useful for the competitions.

3) Remote control: Lab-work for basic tele-operation concepts can also serve as an introduction to the NXT Direct mode. An example is proposed in Fig. 4, which also implements a shared control architecture. The goal is to use the wireless Bluetooth connection to safely tele-operate a mobile robot. Six NXT Direct blocks are linked in a horizontal data flow. These blocks provide a software interface with the NXT brick. Besides, standard LabVIEW blocks are used for keyboard interface and timing. Details of the shared control method and the inverse kinematics are hidden in user-defined sub-blocks.

B. Competitions

As a complement to directed lab work, this section proposes three competition examples that require adding functionalities to the basic control patterns presented above. Their goal is to maintain a high student motivation during the courses, to provoke team work, and to foster students’ ability to cope with new problems. Therefore, these competition projects are not meant to be complex, and can be developed in a

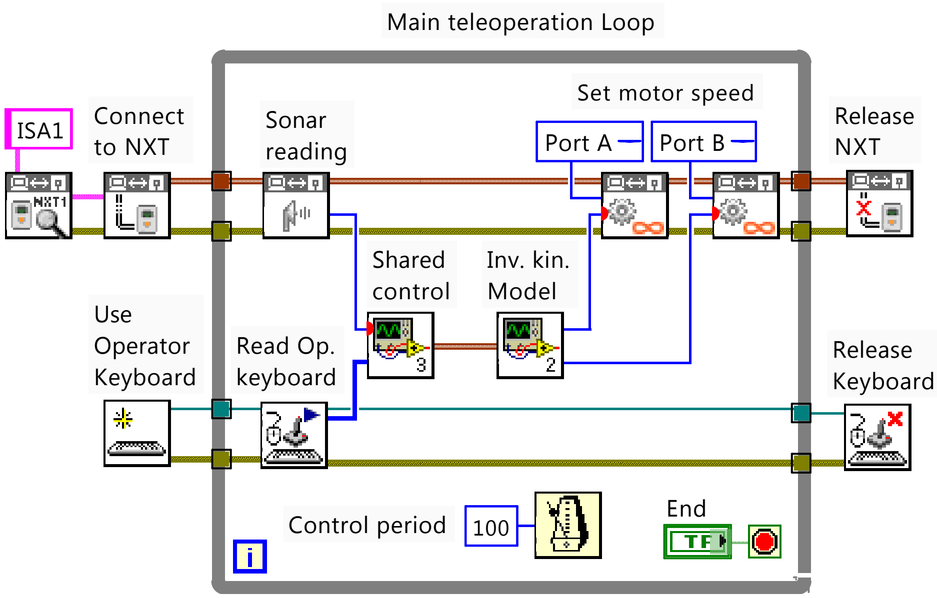


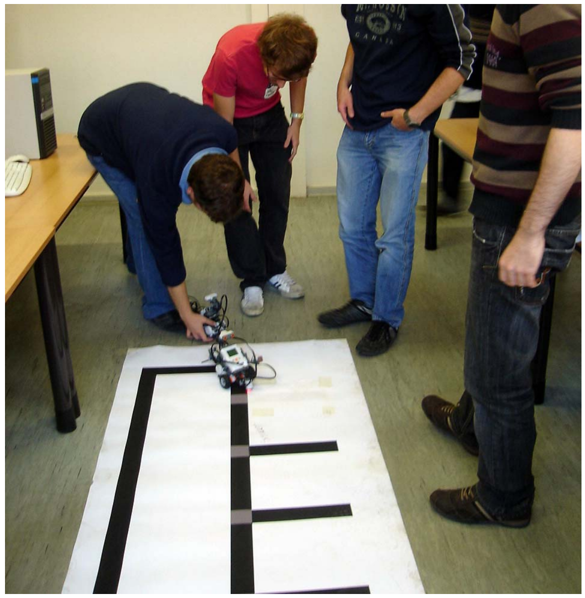
Fig. 4. LabVIEW diagram for a remote control example in NXT Direct mode.

few lab sessions by teams of two students. Each competition can be performed up to three times per team, so that the best trial score is the one that counts. Students are free to decide on the robot configuration and the sensorial system.

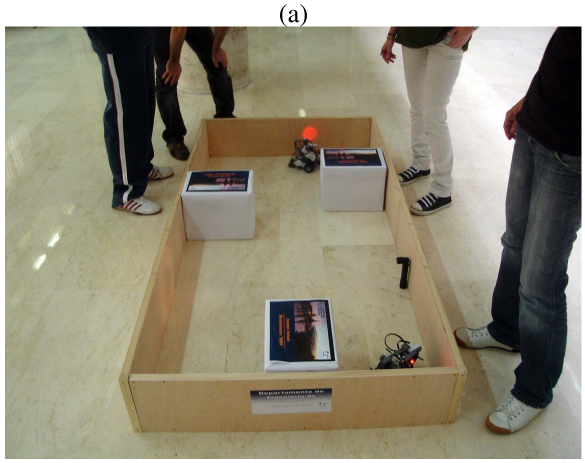
1) Line following: The goal is to follow a path defined by a thick black line on a white ground, including $90°$ turnings (see Fig. 5a). The path is to be completed in both directions, which implies turning back when a landmark obstacle is found at the end of the line. Scores are obtained for successfully passing over path landmarks and for completion time.

2) Reactive navigation: The goal is to find a light source within a closed area with obstacles. This competition requires wall following while avoiding obstacles in unknown positions (see Fig. 5b). Reaching the goal has to be acknowledged by some special action (e.g., a beep). Competition specifications include environment and obstacle dimensions. Scoring is based on completion time.

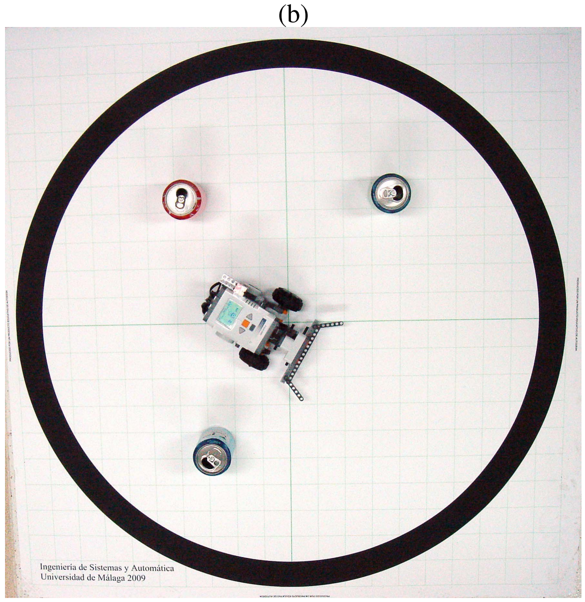
3) Clearing an area: The goal is to take three empty soda cans out of a black circumference of radius $1\,\mathrm{m}$ drawn on white floor (see Fig. 5c). This competition requires detecting randomly placed objects, taking them out of the perimeter, and signaling task completion. Points are given for each can removed, for signaling, and for the best time.



(a)

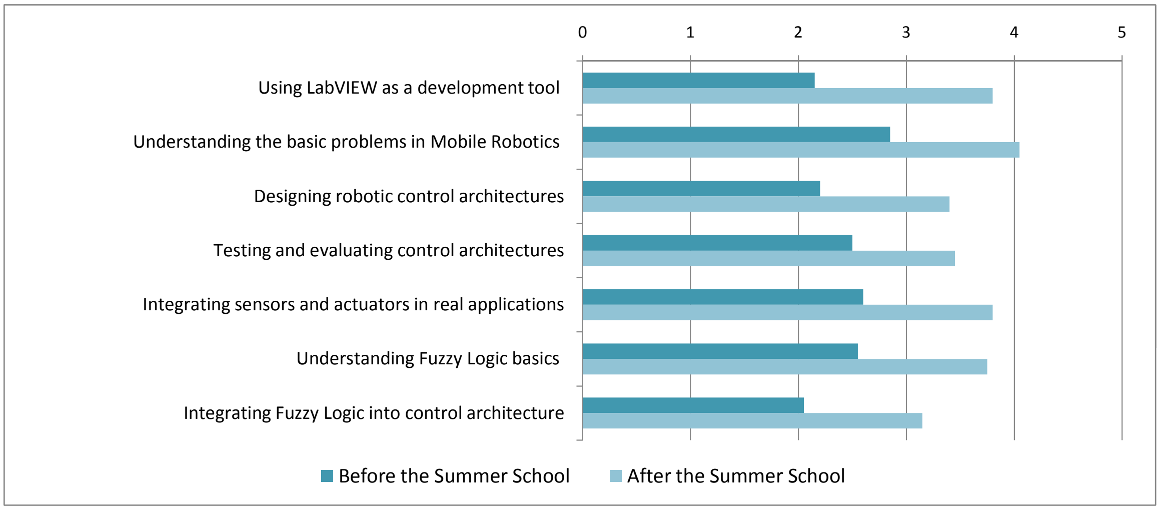


(b)

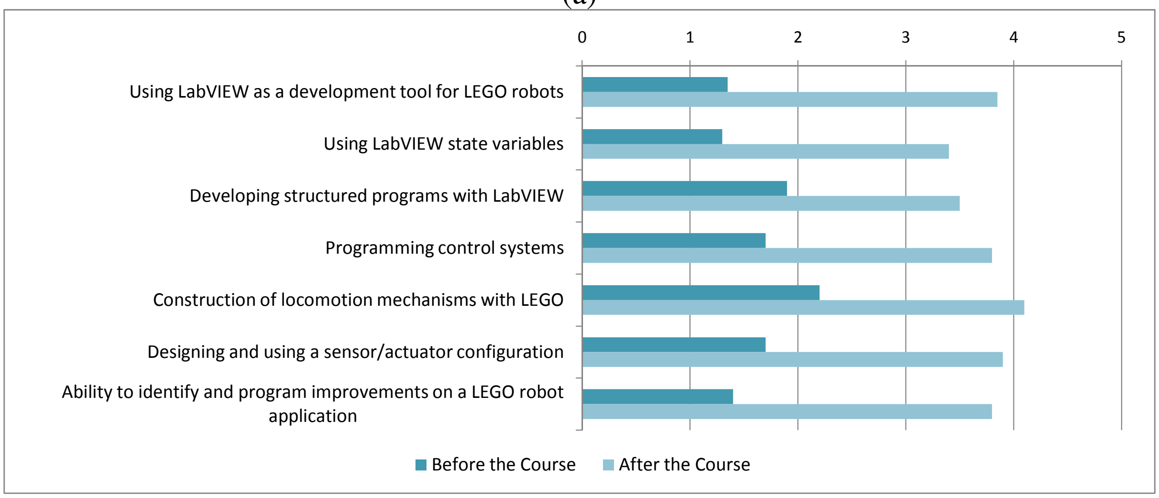


(c)

Fig. 5. Competition layouts. (a) Line Following. (b) Goal seeking. (c) Clearing an area.



(a)



(b)

Fig. 6. Student perception of acquired competencies: (a) Summer School. (b) Mobile robotics course.

V. RESULTS

A. Student Feedback

The pedagogical goal of both experiences was that of having the students acquire the sets of competencies listed in Fig. 6. After the final competition, all participants were requested to fill in an anonymous questionnaire to evaluate their perception of prior and acquired competencies. The average results are depicted in the figure on a scale from 1 (minimum) to 5 (maximum).

The mean value for all acquired competencies is very similar in both experiences (3.63 and 3.76 for the Summer School and Mobile Robotics, respectively). This similarity is interesting if compared with the mean value for prior competencies, which was considerably higher for the Summer School (2.41 against 1.65), where students with a special interest in the field had been selected. This indicates that the proposed tools and methodologies can achieve a good pedagogical result for students with different initial competence levels. Interestingly, the last competency in Fig. 6(b), which is ultimately related to self confidence in the face of new problems, obtains very good results.

B. Discussion

LEGO Mindstorms NXT was first proposed for the Summer School on Mechatronics to serve as an integrating lab-work solution for as many courses as possible. LabVIEW was chosen because some teachers were already using it for other courses and many students were familiar with it. Their experience was that this tool had a short learning curve, so more time could be devoted to specific subject contents. As NXT bricks directly support LabVIEW, the combination seemed promising. The same reasons, as well as the success of the Summer School, determined the choice of this platform for the mobile robotics course.

In general, the response of students to the proposed lab-work has been very positive. It was observed that most students had been working with the robots on their own. A high motivation can also be deduced from student suggestions about follow-up advanced courses on related subjects, such as learning robots.

As for the competitions, all teams completed the goals, and most of them in the first trial. In the line following and reactive navigation competitions, failures to reach the goal were due to gain adjustment for the line or wall following controller. For clearing an area, the range thresholds and angular speed were critical parameters to achieving a maximum score. Finally, as the completion time was a key factor in deciding the winner, students had to tune and improve the control methods in order to get the maximum travel speed.

VI. Conclusions

The paper proposes lab-work and student competitions based on the of LEGO Mindstorms NXT kits and LabVIEW. The application of this instructional material was tested in two different experiences with senior undergraduate engineering students: an intensive Summer School on Mechatronics, and a one-semester course on mobile robotics.

Instead of the default NXT Education Software, programs were developed using standard LabVIEW. Basic examples have been proposed here for three laboratory practices. These examples can be provided as a model to students who are not proficient in this development environment. In particular, the two alternative execution modes supported by the NXT add-ons have been addressed: NXT Toolkit, for stand-alone performance, and NXT Direct, for more powerful solutions run on a computer.

From an educational point of view, a high level of student motivation has been observed by the teachers, with the competitions driving their interest in learning. It was noted that since the main guidelines and rules are given to the students in advance, they focus on the applicability of lectures and lab work to the competition. Accordingly, student surveys have shown a significant improvement in their acquiring the course competencies. For the future, the proposed educational platform will be evaluated for courses on other mechatronics-related subjects.

ACKNOWLEDGMENTS

The authors are grateful to the rest of the teachers in the 2008 Summer School on Mechatronics: Prof. Dr. techn. K. Janschek, PD Dr.-Ing. A. Braune, Prof. Dr.-Ing. habil. R. Merker, Prof. Dr.-Ing. habil, R. Schüffny, from the Technical University of Dresden; and Prof. Dr. V. F. Muñoz, Prof. Dr. N. Guil-Mata, Prof. Dr. O. Plata-González, and Dr. F. Vidal-Verdú from the University of Málaga. The authors would also like to acknowledge the valuable contributions of Dr. J. L. Martinez, from the University of Málaga, to the Mobile Robotics course.

REFERENCES

[1] M. K. Habib, "Mechatronics - a unifying interdisciplinary and intelligent engineering science paradigm," *Industrial Electronics Magazine*, vol. 1, no. 2, pp. 12–24, 2007.

[2] S. Das, S. A. Yost, and M. Krishnan, "A 10-year mechatronics curriculum development initiative: Relevance, content, and results - Part I," *IEEE Transactions on Education*, vol. 53, no. Forthcoming, pp. 00–00, 2009.

[3] C. Buiu, "Hybrid educational strategy for a laboratory course on cognitive robotics," *IEEE Transactions on Education*, vol. 51, no. 1, pp. 100–107, 2008.

[4] R. M. Parkin, "The mechatronics workbench," *Computing and Control Engineering Journal*, vol. 13, no. 1, pp. 16–20, 2002.

[5] B. Erwin, M. Cyr, and C. Rogers, "LEGO Engineer and RoboLab: Teaching engineering with LabVIEW from kindergarten to graduate school," *Int. J. Engng Ed.*, vol. 16, no. 3, pp. 181–192, 2000.

[6] A. J. Hirst, J. Johnson, M. Petre, B. A. Price, and M. Richards, "What is the best programming environment/language for teaching robotics using LEGO Mindstorms?" *Artificial Life and Robotics*, vol. 7, no. 3, pp. 124–131, 2003.

[7] S. H. Kim and J. W. Jeon, "Introduction for freshmen to embedded systems using LEGO Mindstorms," *IEEE Transactions on Education*, vol. 52, no. 1, pp. 99–108, 2009.

[8] D. Mioduser, S. T. Levy, and V. Talis, "Episodes to scripts to rules: concrete-abstractions in kindergarten children's explanations of a robot's behavior," *Int J Technol Des Educ*, vol. 19, pp. 15–36, 2009.

[9] M. Barak and Y. Zadok, "Robotics projects and learning concepts in science, technology and problem solving," *International Journal of Technology and Design Education*, 2007.

[10] E. M. Jimenez Jojoa, E. C. Bravo, and E. B. Bacca Cortes, "Tool for experimenting with concepts of mobile robotics as applied to children's education," *IEEE Transactions on Education*, no. Forthcoming, pp. 1–8, 2009.

[11] E. Wang, "Teaching freshmen design, creativity and programming with LEGOs and LabVIEW," in *Proc on 31st Annual Frontiers in Education Conference*, vol. 3, Nagoya, Japan, 2001, pp. 11–15.

[12] A. Behrens, L. Atorf, R. Schwann, B. Neumann, R. Schnitzler, J. Ballé, T. Herold, A. Telle, T. G. Noll, K. Hameyer, and T. Aach, "MATLAB meets LEGO Mindstorms - A freshman introduction course into practical engineering," *IEEE Transactions on Education*, no. Forthcoming, pp. 1–12, 2009.

[13] V. Papadimitriou and E. Papadopoulos, "Putting low-cost commercial robotics components to the test - development of an educational mechatronics/robotics platform using LEGO components," *Robotics and Automation Magazine*, vol. 14, no. 3, pp. 99–110, 2007.

[14] B. van der Vlist, R. van de Westelaken, C. Bartneck, J. Hu, R. Ahn, E. Barakova, F. Delbressine, and L. Feijs, *Technologies for E-Learning and Digital Entertainment*, ser. Lecture Notes in Computer Science. Springer Berlin / Heidelberg, 2008, vol. 5093/2008, ch. Teaching Machine Learning to Design Students, pp. 206–217.

[15] The MathWorks, "LEGO Mindstorms NXT software for MATLAB and Simulink," accessed Feb. 2, 2010 [Online]. Available: http://www.mathworks.com/programs/lego-mindstorms-nxt-software/.

[16] A. García-Cerezo, J. Gómez-de-Gabriel, J. Fernández-Lozano, A. Mandow, V. F. Muñoz, F. Vidal-Verdú, and K. Janschek, "Using LEGO robots with LabVIEW for a summer school on mechatronics," in *Proceedings of the 2009 IEEE Int. Conf. on Mechatronics*, Malaga, Spain, 2009, pp. 1–6.

[17] T. L. Schwartz and B. M. Dunkin, "Facilitating interdisciplinary hands-on learning using LabVIEW," *Int. J. Engng Ed.*, vol. 16, no. 3, pp. 218–227, 2000.

[18] M. Krishnan, S. Das, and S. A. Yost, "A 10-year mechatronics curriculum development initiative: Relevance, content, and results - Part II," *IEEE Transactions on Education*, no. Forthcoming, pp. 1–7, 2009.

[19] D. Consonni and A. C. Seabra, "A modern approach to teaching basic experimental electricity and electronics," *IEEE Transactions on Education*, vol. 44, no. 1, pp. 5–15, 2001.

[20] M. Yoder and B. Black, "Teaching DSP first with LabVIEW," in *4th IEEE Signal Process. Educ. Workshop*, 2006, pp. 278–280.

[21] C. Salzmann, D. Gillet, and P. Huguenin, "Introduction to real-time control using LabVIEW with an application to distance learning," *International Journal of Engineering Education*, vol. 16, pp. 255–272, 2000.

[22] F. Adamo, F. Attivissimo, G. Cavone, and N. Giaquinto, "SCADA/HMI systems in advanced educational courses," *IEEE Transactions on Instrumentation and Measurement*, vol. 56, pp. 4–10, 2007.

[23] D. Hercog, B. Gergič, S. Uran, and K. Jezernik, "A DSP-based remote control laboratory," *IEEE Transactions on Industrial Electronics*, vol. 54, no. 6, pp. 3057–3068, 2007.

[24] C. I. Nitu, B. S. Gramescu, C. D. P. Comeaga, and A. O. Trufasu, "Optomechatronic system for position detection of a mobile mini-robot," *IEEE Transactions on Industrial Electronics*, vol. 52, no. 4, pp. 969–973, 2005.

[25] T. Chang, P. Jaroonsiriphan, M. Bernhardt, and P. Ludden, "Web-based command shaping of cobra 600 robot with a swinging load," *IEEE Transactions on Industrial Informatics*, vol. 2, no. 1, pp. 59–69, 2006.

[26] A. García-Cerezo, A. Mandow, J. L. Martínez, J. Gómez-de-Gabriel, J. Morales, A. Cruz, A. Reina, and J. Serón, "Development of ALACRANE: A mobile robotic assistance for exploration and rescue missions," in *IEEE International Workshop on Safety, Security, and Rescue Robotics (SSRR2007)*, Rome, Italy, 2007.

[27] National Instruments Corporation, "Getting started with the LabVIEW Toolkit for LEGO MINDSTORMS NXT," Available online: http://www.ni.com/pdf/manuals/372573a.pdf, 2008.

Jesús Gómez-de-Gabriel received the Engineering and Ph.D. degrees in computer science from the University of Málaga, Spain, in 1990 and 1999, respectively. He is currently an Associate Professor with the Department of Systems Engineering and Automation, University of Málaga. Dr. Gómez-de-Gabriel has led a project on telerrobotic surgery and has participated in medical robotics projects and other projects related to mobile robots and factory automation. He has authored a book on telerobotics and is the author or coauthor of more than 30 international papers and patents. His current research interests include mechatronics education, medical robotics, and indoor mobile robotics.

Anthony Mandow (M´08) received the Engineering and Ph.D. degrees in Computer Science from the University of Málaga, Málaga, Spain, in 1992 and 1998, respectively. He is currently an Associate Professor with the Department of Systems Engineering and Automation, University of Málaga. He has been engaged in several robotics and automation projects. He has authored or coauthored more than 30 conference and journal papers. His current research interests include field robotics, robot learning, search and rescue operations, 3-D perception, and vehicle motion control. Dr. Mandow was the Organizing Chair of the 2009 IEEE International Conference on Mechatronics. Currently, he is serving as a Guest Associate Editor of the IEEE Transactions on Industrial Electronics.

Jesús Fernández-Lozano received the M.E. degree in Electrical and Electronic Engineering from the University of Málaga in 1997 and a Dr.-Eng. degree in Robotics from the same university in 2002. He is currently an Associate Professor in the Department of Automation and Systems Engineering. His main research interests are surgical robotics, and automatic fault detection and diagnosis. As a Deputy Director of the School of Industrial Engineering of the University of Málaga, he is responsible for the adaptation to the European Higher Education Area.

Alfonso J. García-Cerezo (M´94) received the Ind. Electr. Eng. and the Doctoral Eng. degrees from the Escuela Tecnica Superior de Ingenieros Industriales of Vigo, Vigo, Spain, in 1983 and 1987, respectively. From 1983 to 1988, he was an Associate Professor with the Department of Electrical Engineering, Computers, and Systems, University of Santiago de Compostela, Santiago de Compostela, Spain, where he was an Assistant Professor from 1988 to 1991. Since 1992, he has been a Professor of system engineering and automation with the University of Málaga, Málaga, Spain, where he was the Head of the Escuela Técnica Superior de Ingenieros Industriales de Málaga from 1993 to 2004, is currently the Head of the Department of System Engineering and Automation, and is also responsible for the Instituto de Automática Avanzada y Robótica de Andalucía. He has authored or coauthored about 150 journal articles, conference papers, book chapters, and technical reports. His current research interests include mobile robots and autonomous vehicles, surgical robotics, and mechatronics and intelligent control. He has also been involved in more than 15 research projects over the past ten years.

Prof. García-Cerezo is a member of the International Federation of Automatic Control, the Spanish Production Technology Automation and Robotics Association, and the Comité Español de Automática. He was the General Chair of the 2009 IEEE International Conference of Mechatronics. Since September 2008, he has been a Coordinator of the Spanish Thematic Group of Robotics.