Space Maker: A Place Where Creativity, Innovation and Hands-on Learning Join to Improve Engineering Education

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Abstract—**Traditional engineering education has been successful until the end of the 20th century. However, the fundamental technological changes of the past decade pose us the question whether this traditional education approach meets the needs of the 21st. century. It is very likely that our future engineers will have to face multidisciplinary problems, and that they will need a systemic approach to solve them. To meet these challenges it is necessary to revise the existing engineering curricula, incorporating facilities where students can design and implement projects early in the curriculum and integrated throughout, experiencing first hand how theory, computer simulation and experiments are used to develop solutions to engineering problems. This corresponds to the well known paradigm of hands-on learning. With these goals, Space Maker was created. It is a facility where students can develop their own projects, or projects proposed by faculty members as part of the courses they teach, allowing them to develop STEM (Science, Technology, Engineering and Mathematics) skills, as well as the capabilities for team work and to communicate ideas. In this paper, several projects being carried out at Space Maker by Electronic Engineering students, are described. The projects are in the areas of mobile robots and signal processing.**

Keywords—*Hands-on Learning; Engineering Curriculum Development; Project Development and Implementation; Problem-based Learning; Team Work Skills.*

I. Introduction

The fast rate of development of information and communication technologies (ICT) is producing drastical changes in our everyday life. This has modified the way we communicate to each other, the way we get informed, the way we exchange documents and other data, the way we approach the solution of engineering projects, for instance through the use of computer-aided design (CAD) software, etc. It is then reasonably to expect that changes should also be made in education, to adapt to the new technologies, and to take advantage of the ubiquity of access to information (connectivity everywhere and to everything) [1], [2]. In this context, the rôle of educators should change from transmitting knowledge, which is now available in the web, to teach the students how to find it, and to encourage them to design their own avenues for learning. Particularly in Engineering Education, the *hands-on learning* paradigm is gaining widespread support, especially in the areas of signal processing, robotics, automatic control and communications. See for instance the articles [3], [4] and [5] in the "Special Article Series on Signal Processing Education vía Hands-on and Design Projects" appearing in the January 2017 Issue of the IEEE Signal Processing Magazine [6], and the article [7], in the Signal Processing area. Interesting ideas on Innovations in Undergraduate Control Education are presented in the Special Section appearing in the October 2004 Issue of the IEEE Control Systems Magazine [8].

A revision of the existing engineering curricula is then needed, incorporanting activities of project design and implementation early in the curriculum and integrated throughout, where students can experience first hand how theory, computer simulation and experiments are used to solve engineering problems. In this context, interdisciplinary comes into play when dealing with projects that try to solve real-world problems.

With these goals, a new facility (*Space Maker)* was recently made available to our students, provided with a variety of equipments and instrumentation, where they can develop their own projects, or projects proposed by Faculty members as requirements of the courses they teach. The purpose of the facility is also to estimulate the creativity of the students and to help them to develop STEM (Science, Technology, Engineering and Math) skills, as well as some social skills such as communication capabilities, the ability for team work and the capability to learn by themselves in a continuous and autonomous way.

The rest of the paper is organized as follows. In Section II, a description of *Space Maker*, and the available equipment is provided. The way students can access the facility is also described. A number of projects developed by Electronic Engineering students at *Space Maker* are described in Section III. Finally, some concluding remarks are given in Section IV.

II. Facility Description

A. The Place

The facility is located in a new building shared by the School of Electronic Engineering and the School of Civil Engineering. Panoramics views of the facility can be seen in Fig. 1.

Figure 1: Panoramic views of Space Maker.

The facility is open from 08:00 to 18:00 hours, from Monday to Friday, and advanced Electronic Engineering students are in charge of providing assistance to the students using the facility. The feasibility of the proposed projects is evaluated by an Academic Committee. As already mentioned, projects can be proposed by individual students or student teams, or by Faculty members as part of the courses they teach. For the time being, Space Maker is being mainly used by Electronic Engineering students, but actions are being taken by the authorities to promote its use by students of the different Engineering degrees being offered at the University. A set of projects, with different levels of complexity, is being developed to engage students early in the curricula.

Students participating in projects at Space Maker are asked to provide documentation once the project is finished.

B. The Equipment

The facility is equipped with a 3D printer, a CNC machine to build Printed Circuits Boards (see Fig. 2), a Laser cutting machine, a Digital Osciloscope, a Function Generator, Power Supplies, a Digital Multimeter, several personal computers, several robotic platforms and microcomputers (Arduino, Raspberry Pi 3B, Odroid), robotic sensors (digital cameras, ultrasound, infrared). The equipment was partially funded by a local company (Techint) within the framework of its University Funding Program.

Figure 2: A 3D printer and a CNC machine to build PC Boards.

III. Current Projects

In this section, some of the projects being carried out at Space Maker will be described. Most of them are related to the areas of signal processing, robotics and control.

A. Real Time Sound Source Localization and Tracking System

The project was carried out by the fourth, fifth and sixth authors for a Student Competition within the 2017 Electronic Engineering Open Days at our University. Five teams participated in the Competition which consisted in designing and implementing a Real Time Sound Source Localization and Tracking System, based on a microphone array. The microphone array is mounted on a servo. An embedded microprocessor computes the time difference of arrival (TDOA) of the acoustic signal to the microphones, which is then used to compute the angle of incidence of the acoustic wave. This information is then used to control the servo so that the baseline of the array orientates in the direction of the sound source. The device is shown in Fig. 3.

The proposed solution makes use of an audio CODEC based on the PCM2904 integrated circuit. A Raspberry Pi 3B+ was used as the processing unit, and to control the servo through the PWM output. A correlation based algorithm in the FFT domain was implemented to compute the angle of arrival of the acoustic wave.

A paper describing the system was presented at the Student Competition within the 47th Argentine Congress on Informatics (JAIIO 2018), being the recipient of the Best Student Paper Award [9].

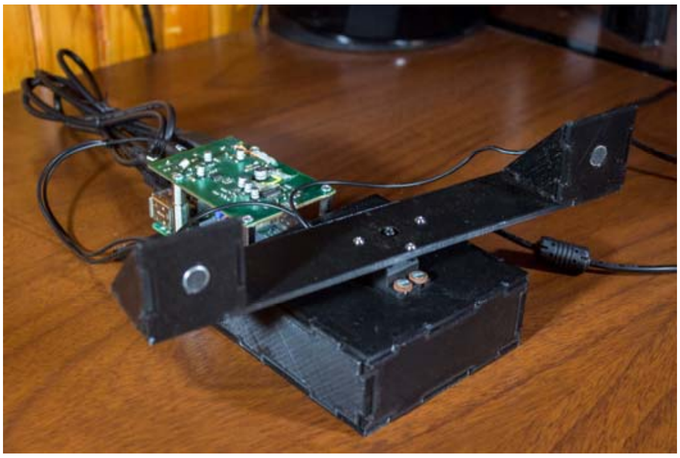

Figure 3: Real Time Sound Source Localization and Tracking System.

B. Prototype Robot for Computer Vision and Control Applications

The project was carried out by the eighth author as an extra curricular activity for the third year Electronic Engineering course on Signals and Systems, under the supervision of the second and third authors.

The designed robot is composed by a platform with three wheels. Two of them can be controlled independently while the third one is used for stability. The robot also includes a webcam provided with pan and tilt control, and a proximity sensor. The robot is depicted in Fig. 4.

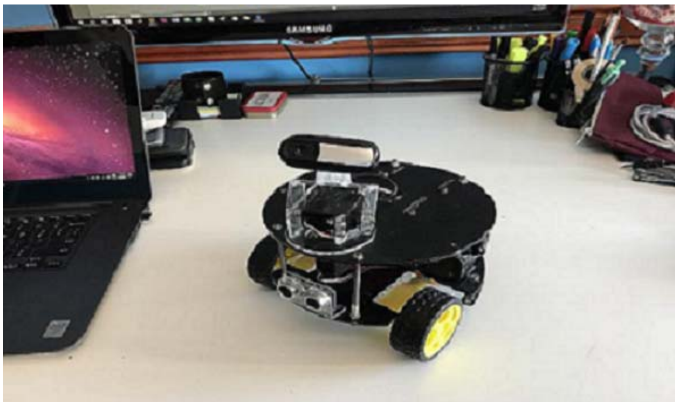

Figure 4: Three wheel robot with camera and proximity sensor.

The robot wheels are driven by 2 DC motors, while the camera by two servos for panning and tilting. The robot includes a Raspberry Pi B+ computer, an Arduino, a Logitec USB cam, and a TP-Link WiFi Dongle.

The Raspberry Pi controls all the characteristics of the robot, such as wheels and camera movements, WiFi connection and image acquisition. It also provides the interfase to control the robot via Secure Shell Service (SSH). The Arduino is used to generate the Pulse Width Modulated (PWM) signals to control the DC and servo motors.

The robot can be accessed via a WiFi connection. It has an image streaming service to access in real time to the images acquired by the camera, and a SSH communication service to control it.

The robot can also be employed to perform on-board processing, for example, following a predefined trajectory, and recognizing or locating different objects in the scene. In this case, the corresponding processing routine can be loaded and executed on the Raspberry Pi computer. In addition, the robot can be controlled remotely, for instance for computer vision applications with high computational load, such as automatic navigation based on images. In this case, the image processing routine can be executed in a remote computer, receiving the images from the robot, and sending back the corresponding commands to control the wheels or the camera position.

A python script was developed to track the movements of a person's face with the camera, by controlling the servo brackets appropriately. This application is executed in a remote computer, and it makes use of the software library *paramiko* for communicating with the robot, and the *MatplotLib* library for displaying the images from the camera. For this implementation *OpenCV* library was used to process the images from the camera, in order to detect and to estimate the positions of faces in the images. For this task, the well-known Viola-Jones face detection algorithm was employed. The algorithm retrieves the bounding box for every fase detected in the image. The idea is to move the camera so that the detected fase is centered in the image.

For every image from the camera, the algorithm computes the relative position from the face to the center of the image and moves the servos accordingly. The motions of the servos to pan and tilt the camera are proportional to the distance from the face to the center of the image, and to the size of the face in the image. If the face to be tracked is away from the camera, its size on the image will be rather small in comparison to the case of being closer to the camera. Therefore, the panning and tilting angles will be different, even though the distance between the center of the face and image will be the same for each case. Additionally, in order to avoid constant oscillations around the face, four boundaries around the center of the image are defined. If the center of the face is inside those boundaries, the robot will stop moving the camera until the face is detected outside it. If more than one faces are detected in the image, the algorithm will track the one that is closer to the camera, *i.e.*, the one that is represented with a bigger bounding box.

Another application that was implemented was a python script to detect and read QR Codes.The algorithm is able to read and report back the information, included in the QR code, via the terminal or writing it in streamed images from the robot. This algorithm also is able to determine the location of the QR code in the image. This can potentially allow other more sophisticated tasks, such as automatic inventory in a warehouse or a factory without the need of a human operator. The information included in the QR code could be also used to indicate the robot to perform different tasks, for example to move to a certain position, or to analyze a particular object in the scene marked with a QR Code.

It is planned to implement Deep Learning algorithms to allow the autonomous movement of the robot following a path.

A paper describing the robot and its possible applications was presented at the Student Competition within the 46th Argentine Congress on Informatics (JAIIO 2017), being the recipient of the Best Student Paper Award [10].

C. *Vision-based flight control of a drone*

The project is being carried out by the fifth and seventh authors as their Final Year Electronic Engineering Project, under the supervision of the second and third authors. The goal of the project is to use the information acquired by a camera mounted on a drone to detect and track moving objects.

In a first stage, the communication scheme depicted in Fig. 5 has been proposed. The images captured by the camera are transmitted via WiFi to the computer (a Raspberry Pi) which performs the processing for the localization of the object, which is marked with a QR-type code. The control signals are then generated by an Arduino microcontroller and transmitted through a radio-frequency link to the drone.

Due to the latency of the radio link, an alternative approach using an onboard computer (Raspberry Pi + Arduino) is being considered. Preliminary experiments have shown that a much better performance can be achieved with this approach. The project is expected to be finalized by the end of the present year.

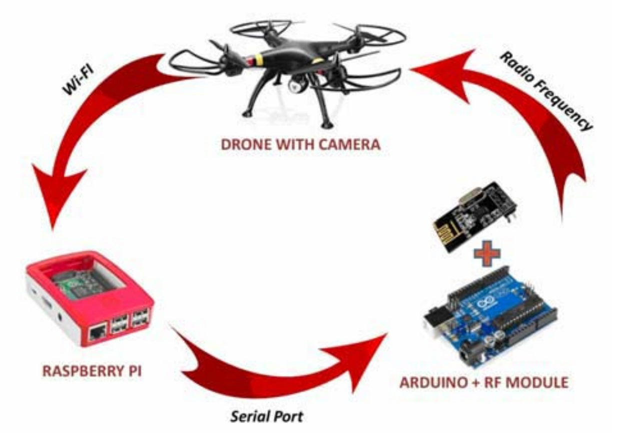

Figure 5: Communication scheme for the flight control of the drone.

D. *Prototype Delta Robot*

The project is being carried out by the last two authors as their Final Year Electronic Engineering Project, under the supervision of the second and third authors. The goal of the project is to design and built a Delta Robot (a.k.a. "pick-and-place" robot) provided with artificial vision and end manipulator. Algorithms for the detection and classification of different objects are planned. The project is expected to be finished by the beginning of next year. A 3D rendering of the robot is depicted in Fig. 6.

E. *Vision-based detection and classification of soda bottle caps*

The project has been proposed for the Student Competition during the 2018 Electronic Engineering Open Days. Ten teams have enrolled for the Competition. The goal of the project is to design and implement an automatic system for the classification of soda bottle caps according to their color, based on the images acquired by a web cam. Students are provided with a Raspberry Pi computer, Arduino, servos, and the webcam. Awards for the best solutions will be given during the Electronic Engineering Open Days, where the participating teams will present their proposals in a Poster Session.

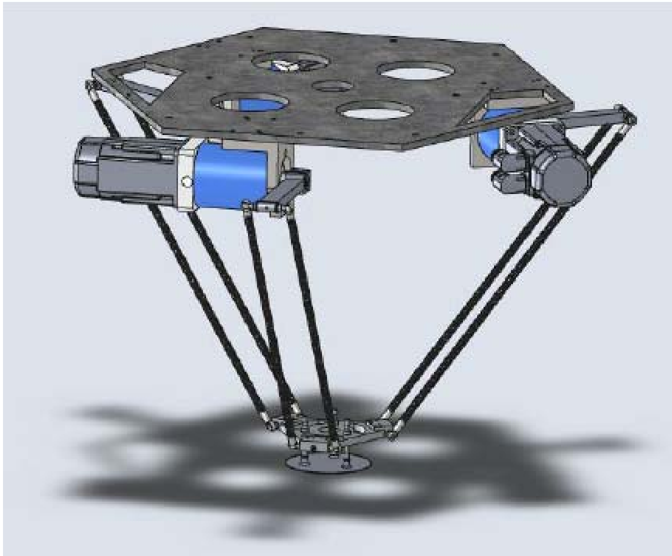

Figure 6: A 3D rendering of the Delta Robot.

IV. Concluding Remarks

A revision of the Engineering curricula is needed to accommodate to the vertiginous rate of development of Information and Communication Technologies. In this context, it is necessary for the students to be faced with activities of project design and implementation from the beginning of their studies. University institutions must then create facilities where students can work on engineering projects, estimulating their creativity, and allowing them to develop team work capabilities and communication skills.

In this paper, a description of such a facility recently created at the Universidad Nacional de Rosario has been presented, together with a series of projects being carried out by Electronic Engineering students. It is expected a more widespread use of Space Maker by other Engineering programs at this university.

ACKNOWLEDGMENT

The authors would like to thank the financial support, within the framework of its University Funding Program, of the local company Techint.

REFERENCES

[1] M.T. Garibay, “Inclusión de las TICs en Educación Superior. Experiencia de un Curso para Docentes sobre Incorporación de las TICs como Herramientas Didácticas”, Proceedings of 6to. Seminario Internacional de Educación a Distancia, Mendoza, Argentina, 2013.

[2] CONFEDI (Consejo Federal de Decanos de Ingeniería), 3er. Taller sobre Desarrollo de Competencias en la Enseñanza de la Ingeniería en Argentina. Experiencia Piloto en las Terminales de Ing. Civil, Electrónica, Industrial, Mecánica y Química, Villa Carlos Paz, Argentina, 2006.

[3] T. Schäck, M. Muma and A.B. Zoubir, “Signal Processing Projects at Technische Universität Darmstadt”, IEEE Signal Processing Magazine, Vol. 34, No. 1, pp. 16-30, January 2017.

[4] Q. Zhao, Y. Ren, Y.Jiang and C. Zhang, “Hands-on Learning Through Racing”, IEEE Signal Processing Magazine, Vol. 34, No. 1, pp. 31-39, January 2017.

[5] E. G. Larsson, D.Daney, M. Olofsson and. S. Sörman, “Theaching the Principles of Massive MIMO”, IEEE Signal Processing Magazine, Vol. 34, No. 1, pp. 40-51, January 2017.

[6] H. Godrich, A. Nehorai, A. Tajer, M.S. Greco, and C. Zhang, “Special Article Series on Signal Processing Education via Hands-on and Desing Projects”, IEEE Signal Processing Magazine, Vol. 34. No. 1, pp. 13-15, January , 2017.

[7] M. Simoni and M. Aburdene, “Lessons Learned from Implementing Application-oriented Hands-on Activities for Continuous-Time Signal Processing Courses”, IEEE Signal Processing Magazine, Vol. 33, No. 4, pp. 84-89, July 2016.

[8] D. S. Berstein and H. Ashrafiuon, “Innovations in Undergraduate Control Education, An Introduction to the Special Section”, IEEE Control Systems Magazine, Vol. 24, N0. 5, pp. 18-19, October 2004.

[9] M. Moya, R. Marcuzzi and L. Soria, “Desarrollo de un Sistema de Localización y Seguimiento en Tiempo Real de una Fuente Sonora” (“Design of a Real Time Localization and Tracking of a Sound Source System”), Proceedings of the 47º Jornadas Argentinas de Informática (JAIIO 2018), Buenos Aires, Argentina, August 2018.

[10] A. Massetti, “Prototype Robot for Computer Vision and Control Applications”, Proceedings of the 46º Jornadas Argntinas de Informática (JAIIO 2017), Còrdoba, Argentina, September 2017.

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