Robotics Application Project-Oriented Programming: Learning and Competition

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Abstract: Project activities are increasingly present in the curriculum of engineering courses. Projects involving robotics competitions are always attractive to the students and provoke their engagement. The work presents a project-oriented learning experience for electrical engineering students since a college freshman in the first semester of the graduation. Students are challenged to solve logic problems and participate in a sumo wrestling competition with their robots. Before meeting the challenge, students are trained in the LabVIEW® programming language. Almost all the students participating in the project had never programmed in this or another language. This work presents the success obtained in teaching programming involving concepts of robotics and a programming language focused on industrial automation. In a multidisciplinary context, the students had the opportunity to have an introduction to concepts of robotics, programming logic, sensors and automation.

Keywords: Robotics, Learning, Programmable, automation, competition

1. Introduction

Electric devices and mechanical components compose a robot. An electrical robotic system by electric view consists of acting sensors, actuators, control systems and communication systems. From the mechanical engineering point of view, a robot is classified according to its movements and degrees of freedom, that is, in mechanics the study and development of robots passes through the appropriate materials to be used in its construction, for anatomical reasons and questions and movements to be executed by the robot [1].

Robotics encompasses mechanical, electronic and computer technologies. Besides, other areas are employed in the development of robots such as control, microelectronics, artificial intelligence, human factors and production theories. In new robotics (modern age), there are researches and developments of robots titled humanoid or anthropomorphic. These are created with human likeness, to do specific activities and not a decoy, although most people do not see robots in this way. They robots currently have been employed in
industries in other configurations. The application of the moment, so-called of fourth industrial revolution or 4.0 industry concepts, robots rise doing the repetition tasks, automatic issues, mechanical arms, smart cranes, rolling mats, etc.

Robots are on the scene like great actors in the automation area. They made the new technology, makes uses of mechanical, electrical, electronic and computer systems to control production processes and this knowledge become part of our daily business, in residences, streets and industry. Robotics makes impact on society in the various productive sectors.

The automation of tasks with a certain degree of dangerousness using robots reduces the risks to workers and brings greater comfort and productivity in complicated processes and activities where the human being would traditionally perform. In other hand has an impact on the number of jobs to be offered, it is necessary that the areas of knowledge focused on science and technology enable its students and professionals to deal with robotics and to develop solutions that allow to create new businesses and new jobs that do not yet exist, based on the robot work or machine learning.

At the moment, the spotlights are on the battle bots competition that is become popular, which undergraduate students in engineering are encouraged to develop robots to compete in challenges such as strength, speed, fight, soccer, complex problem solving or task execution [2] The robot competition environment has stimulated students to learn concepts of electronics and programming, important in the formation of the Electrician Engineer.

In traditional programming in College, is through basic structures are applied in a traditional text language such as C, Python, or Java. However, it is perceived that for undergraduate students in Engineering it is not stimulating and not efficient as this approach should be [2]. The initiation of programming with a graphical language with the application in hardware (own robot) is more stimulating and adherent to the universal idea of Engineering. Robotics has been increasingly employed in the several programming, with the advent of hardware and mechanical devices, some works have presented significant results in programming teaching, applying and learning techniques different from traditional ones, who presents great advances with the application of robotic systems in several parts of the new technology world [3,4].

In addition, the fact of the current need for the use of teaching techniques directed to projects in engineering courses. In this context, Universidade Mackenzie (Mackenzie University) created and implemented the integrative projects. These aims provide students with experiences outside the context of traditional classes to develop projects that apply skills and abilities of their undergraduate courses in a practical or applied way. Among the several projects developed by the students in the ambit of the integrating projects of the School of Engineering Mackenzie stands out the Competition of Intelligent Robots. The Competition is based on the Labview® language programming of Lego EV3® [5,6] robots for task resolution and scenarios that apply programming and electronics concepts present in industrial automation systems.

This present work shows the application of a teaching technique of active programming oriented to projects in the robotics context. The college freshman in first semester of the graduation in Electrical Engineering degree program are trained in the LabVIEW® language and are challenged to develop solutions to challenges proposed by teachers. To solve the challenges, all groups of students used the EV3® robotics kit that is based on a 32-bit ARM 7 microprocessor [6]. Three challenges were proposed: in general, students should identify the most suitable sensors and actuators for the robot to perform the task autonomously, assemble the robot with the most appropriate geometry and perform the programming that would allow the robot to solve the challenge. After a two months period training and development students participate in a competition where points are awarded for the execution of the challenges [7].
2. Experimental procedure

The integrating project was offered to students of the Electrical Engineering course at the Mackenzie School of Engineering who study in the beginning of the graduation. The teachers of the course elaborated 3 challenges that required application of sensors and actuators as well as an algorithm that allows the robot autonomy to execute the challenges. Thus, from the reading of sensors the algorithm developed by the students in LabView should trigger the actuators to perform the proposed task, without the need for external controls, that is, an autonomous intelligent robot was implemented.

All participating students in the project were provided with a Lego EV3® kit, which consists of: processing module, ultrasonic sensor, infrared led, photodetector, DC motors, servo motors, gyro and parts for mounting the robot structure. All participants should program the robot in LabVIEW® language. The project was proposed with duration of two and a half months; in this period weekly students were trained in the tool and programming language. In addition, they had the Electrical Engineering lab available outside of class hours to program the robot and perform the tests. The training meetings lasted 1h30 minutes. At the first meeting of the semester, the students were presented with the three challenges to be achieved in the competition.

After the presentation of the challenges, the students are encouraged to develop the code and define the sensors and actuators suitable for solving the challenges. In addition, they have stimulated their creativity to assemble and combine the Lego pieces in order to have the geometry and layout more appropriate to the challenges. The challenges developed by teachers are presented below.

![Figure 1](image)

**Fig. 1**: First challenge proposed in competition of smart robots.

In the first challenge, the robot starts the circuit in the green circle, at first moment, it must move to the red square. This indicates the presence of the bar code being read which represents a binary value. From the reading of this code the robot identified the place in which it should close the route, the blue or yellow circle. Before this, the robot should perform the first curve, identifying the obstacle and bypassing it until returning to the black line after the obstacle. Soon after, it should remain on the black line until the arrival point, corresponding to the bar code.

For the first challenge the following score was awarded: two points for the initial curve, two points for identifying the obstacle, four points for deflecting the obstacle and finding the line on the other side, two points for stopping at the correct place and two points for indicate the binary number of the bar code on the display. Totalizing a maximum of twelve points.
In the second challenge, the robot starts in the yellow circle and it must move to the red square. Again this indicates the presence of a bar code to be read by the robot that represents a binary, even or odd number. After reading the robot should follow the black line until reaching the first purple square, which indicates the presence of a ball in the gray circle. If the bar code on the front of the ball has the same parity of the code read initially the ball must be pushed to the goal in the lower part of the figure, otherwise the ball should be left in place. Regardless, the robot, by simple programming would continue to check the next three balls until the last, and after his autonomous decision, he should follow and finish his command on the yellow circle.

For this challenge the following score was awarded: two points for pushing each ball with the parity bar code equal to the initial one, two points for leaving each ball with the parity bar code different from the initial one, two points for stopping the ball robot in the correct place and two points for indicating the binary number of the initial bar code on the display. Totalizing a maximum of twelve points.

The third challenge consists in a sumo fight. The four participants with the highest score added in the first two challenges performed fight in pairs. The two winners of the semifinal call were faced in a final sumo fight.

The Figure 3 shows the circle used in the battle of the robots of the third challenge of the robot competition and this logo represents the Mackenzie University.

In this challenge the geometry and weight of robots as well as the use of motors are essential for good performance, since it was the decisive challenge of robot competition.
The scores of the sumo-wrestling match came with a two-minute duel. The two competitors were positioned within the black circle and started their programs at the same time as a stopwatch. The goal is for one robot to push the other out of the university logo, that is, out of the circle, and achieving success, were awarded five points for his team. If a robot knocks down the other robot within the circle, the one standing has acquired two points and being inside the circle while the opponent is out grants another point. During the two minutes, the match was restarted as many times as necessary, locking the stopwatch.

3. Results and discussion

Of the nine teams enrolled, eight participated in the competition, and the quitting team stopped attending the training at the beginning of the process, that is, all the groups that were actively present in the class developed confidence in process and demonstrate their results, totaling twenty four student’s competitors. For the first two tracks, the points system developed had a maximum score of 12 points, so that it is possible to directly compare the performance of the 8 participating teams. The score obtained by the teams participating in the competition is presented in table 1, below.

Table 1: Scoring obtained by participants teams in the competition for intelligent robots. Elaborated by the authors.

| Competition | Track 1 | Track 2 | Total |
|-------------|---------|---------|-------|
| Team 1      | 12      | 12      | 24    |
| Team 2      | 12      | 12      | 24    |
| Team 3      | 12      | 10      | 22    |
| Team 4      | 12      | 6       | 18    |
| Team 5      | 12      | 2       | 14    |
| Team 6      | 8       | 2       | 10    |
| Team 7      | 4       | 0       | 4     |
| Team 8      | 4       | 0       | 4     |
| AVERAGE     | 9.5     | 5.5     | 15    |

In both challenges a score of 12 points represents a perfect execution. Scores 10 and 8 indicate that the challenge was solved, but with one or two caveats, possibly an inaccurate bar code reading or a misdirected ball on track 2, or even failure while the robot was making the ride. Therefore, these scores are considered as indicative of which team have successfully performed the challenge and are highlighted in light green in table 1. In yellow are highlighted the performances of the teams that indicate a partial solution of the lane, solved the challenge incompletely, acquiring points through the simplest objectives such as stopping at the end of the course or performing the closed curve of the first lane, for example. In orange are highlighted the executions that did not solve the proposed problem, in them the robot possibly acquired only a minimum of points to begin the route correctly but ended losing the course soon.

The overall performance of the teams in the first challenge was excellent. Six teams achieved significant scores, with five of them acquiring maximum scores. The first challenge was considered as
an important step in the construction of the programming language, playing an introductory role to more elaborate programming.

Thus, this challenge, by encouraging students to develop a language where none of them were accustomed, ended up being the target of greater dedication of time on the part of the students. This performance shows that students are able to learn and apply the LabVIEW® language from the training offered without the need for any previous knowledge of programming languages or previous contact with programming tools. One of the two teams that did not obtain a good result was evidenced that it was lack of commitment and not failure of project, since this team did not participate actively of the project.

The expected solution for this challenge involved a use of the light sensor to identify the bar code and the black line. Then the ultrasonic sensor to identify the obstacle, bypass it and again with the light sensor identify the stopping point.

The Figure 4, below, presenting a flowchart of the process.

![Flowchart of the code to solve the first challenge of the competition.](image)

**Fig. 4:** Flowchart of the code to solve the first challenge of the competition.

The creativity character of the competition became apparent when the team’s methods of solution were compared to what was expected. To circumvent the obstacle, for example, some teams introduced non-sensor commands for this task; others used the rotation sensor to ensure that the robot
was always parallel to the box. Another point where diversity of solutions was observed was in the color detection algorithm, so that no team presented the same solution to this problem.

Already in the second challenge, the difficulty was greater when compared to the first, which resulted in his lower medium average score, with only two perfect rides. This happened because before dedicating to the second part of the competition all the teams decided to complete the first part as well as possible, since this was the basis for the second part, since both offered the same amount of points for performing different tasks. Therefore, a good score in this lane indicates a fast resolution of the previous track, which gave an advantage to the groups that became familiar with the tool and programming language, either by attention in the training, or by the presence in the monitoring, or even by the demonstrated pro activity.

What was expected for the second challenge was to use the light sensor for the tasks of reading the bar code, to follow the line and to identify the presence of the bars through the blue indicator on the floor. Another possible method of identifying the bars is using the ultrasonic sensor, which makes the lane simpler since it and is not necessary to read the purple bars with the light sensor. However, no team opted for this solution. This was due to the need to use the ultrasonic sensor to identify the obstacle in track 1 and the easy method of work with the light sensor that the teams had already applied to the solution in the first challenge.

The Figure 5, below, shows a flowchart of the expected solution for the second challenge. In it the robot enters a loop that checks if each ball is to be pushed until the fourth ball is checked. From that moment, the robot continues following the line until it finds the brown circle that indicates the end of the track.

The last round, after the elimination process, was responsible for presenting a challenge beyond programming. Sumo's fight forced the teams to think about how to design a robot that suited both the previous challenges and the new challenge of pushing another robot out of the logo or battle circle. At this stage, the groups that best evaluated this issue stood out. One of the teams chose to install a retractable ramp, an idea that several teams had, but failed to implement.

They choose to prioritize the first two challenges, by given the rule of not changing the robots during the competition and the need to push balls in the second challenge. A team featured in the general competition was the one who found a way to use a ramp without changing the structure of the robot through a dedicated motor to lower the ramp when it was not necessary to use. Another possible strategy was found in the winning team, who used all the pieces of the kit to assemble their robot. In this way, this robot sacrificed speed and maneuvers of the robot, but having greater mass was more efficient to push the opponents of the arena, which proved the superior strategy in sumo battle. As this team had, a code appropriate to the first two challenges managed to succeed in the overall score.
The Figure 6 shows on the left part, the robot with the retractable shovel, and, on the right, the winning robot that had greater mass in relation to the other competitors. The fact that the competition had no mass limit favored the robot with the largest mass in the sumo battle. The Figure 6 below shows the finalists.

![Fig. 6: Robot finalists of the competition.](image)

The robot of the team to the right, better sized the distribution of mass in relation to the power of the engines that was the same for all the searches. The moment of inertia is approximately 50000 g.cm$^2$ of the motor is of extreme importance for the movement of its inertial mass, and its distribution of weight, therefore its density caused the right robot to overcome the duel.
Through the competition, it was possible to verify the stimulus that this project caused in this context, highlighting the commitment and motivation on the part of the students. The first two logic-driven challenges were performed by 50% of the students with full success, and 25% with partial success, and only 25% of the students performed unsatisfactory.

The Figure 7, below, shows the moment of the competition, which took place in the auditorium of Universidade Mackenzie, and was open to the public.

![Fig. 7: Smart Robots Competition moving the campus of Mackenzie University.](image)

4. Conclusion

The robot competition motivated and introduced students in the study of robotics, programming and automation and allowed students entering the electrical engineering course to have contact with innovative technologies linked to their future profession. Students in their first contact with a programming language had the opportunity to learn in a playful mode in a project-oriented way. The experience was successful, which strengthened the application of project-oriented teaching methodologies in electrical engineering education at Mackenzie University. Another relevant factor is the training of students in a very widespread commercial programming language applied in scientific and industrial areas. This experience will strengthen students in subsequent disciplines they will attend.

5. References

[1] CASTILHO, Maria Inês. Robótica na educação: com que objetivos? 2002. (Monografia de Especialização em Informática na Educação) - Universidade Federal do Rio Grande do Sul, Porto Alegre, 2002. Disponível em: Acesso em: 22 março de 2018.
[2] GONÇALVES, Paulo César. Protótipo de um robô móvel de baixo custo para uso educacional. 2007. 87f. Dissertação (Mestrado em Ciência da Computação) – Universidade Estadual de Maringá, Maringá, Paraná, 2007.
[3] Labview (2018). Disponível em: http://www.ni.com/pt-br/shop/labview.html. Acesso em agosto de 2018.
[4] Lego Mindstorms (2014). Disponível em: https://www.lego.com/pt-br/mindstorms/. Acesso em: agosto de 2018.
[5] MAISONNETTE, Roger. A utilização dos recursos informatizados a partir de uma relação inventiva com a máquina: a robótica educativa. Disponível em: www.proinfo.gov.br. Acesso em 20 de março de 2018.
[6] MARTINS, Agenor. O que é robótica? São Paulo, Editora Brasiliense, 2006.
[7] MUBIN, O., STEVENS, C. J., A Review of the applicability of robotics in education, Technology for Education and Learning, 2013