# Robotic projects to enhance student participation, motivation and learning

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We present the various projects developed by our group over the years with the purpose of motivating students and increasing their level of participation in the activities of our group. The students involve range from third semester to final year students. The projects cover various aspects of computer science, electronic and mechanical engineering.

**Keywords:** Project Oriented Learning, Pedagogy, Robotic Manipulators, Mobile Robots, Java Programming.

## 1. Introduction

Engineering students starting their education in various branches of engineering find it difficult to understand and appreciate the value of undergraduate curriculum. Our group has experimented with various robotic projects for second, third and fourth year engineering students designed specifically to improve their learning and understanding of the subjects taught. The list of students starts from those still taking core courses (like physics, mathematics, dynamics, circuits, etc.) and goes up to 8$^{th}$ semester students. The wide variety of projects, their quality and originality gives us confidence that these students can become far more fruitful engineers if given the right type of education. Robots have been a recurring theme in many educational efforts, including, but not limited to child education, engineering education, adult education and even education for physically and mentally challenged persons. The existence of simple platforms like LEGO[1] and Parallax[2] has brought a boom in their applications in primary to university education.

Obviously, our work is not the first attempt of its kind. An extremely large body of literature exists in this area, [3-11]. For example, in [3] authors have tried to integrate robotics research into course and project work in order to enhance and update curricular activities. Their educational goals were: Give students hands-on experience with real problems, give them experience in understanding and implementing principles from primary research literature, give students confidence in their ability and help them develop teamwork skills. Reference [4] focuses on math education using programming of robots. Interestingly enough, they focus attention to school students and have developed a system specifically that helps in teaching mathematics to them. The use of robots in enhancing the quality of education at a university level, using microcontroller based robots, has been discussed in [5] and [6]. In [5] students at sophomore level are being involved in robotic projects. They design, build and test their robots themselves and that helps them later in their education. The authors of [7] use LEGO robots to teach elementary science to school students. Reference [8] has gone to the level of teaching control to eight graders in public schools. This program, working under the G-12 program of NSF has designed and implemented instructional robotics modules for school students. The starting point of their work was the observation that science and mathematics courses begin to focus on applications starting from 8$^{th}$ grade and hence that is the level to attack and modify.

Students in our engineering programs come with various skills to the school and depending upon their background and interests can have highly developed computational, mechanical and/or electronic workshop skills. All these can be invoked in suitably selected robotic projects where they also learn collabora-

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tive and group work. They also have to learn how to use the on-campus engineering workshops and how to search and purchase materials and supplies for their projects. In this paper we present brief summaries of three projects developed and their impact on motivation of the students. We also discuss the various technical skills targeted and how they were evaluated during the project work.

## 2. Mobile Robots in Manufacturing

The applications of mobile, autonomous robots have been studied extensively and the interested reader is referred to [12-15] for various interesting applications and developments. A mobile robot (Automatic Guided Vehicle or AGV) can be inserted in a manufacturing cell to transport some objects from one place to another. Fixed robots (robotic arms) in a cell can put and pick up these objects on AGV. If students do not have enough knowledge to insert an AGV in a cell by connecting it to the main PLC (Programmable Logic Controller), it is possible to use sensors in AGV to interact with fix robots. The AGV with sensors follows a line made on the floor and detects when an object is placed on it to transport it to another place and waits till the object is removed from it. At this moment the AGV returns to base position following the line, to pick up and transport another piece.

The right form to do that is by programming the PLC that controls every component in the manufacturing cell. This option has two main problems. The first one is that some students do not have enough knowledge to program and modify a ladder program in a PLC. The second one is that the ladder program was made by the sellers of the cell and we do not have any documentation about it. Translating number signals in ladder program to physical signals in manufacturing cell would take too much time for students. The number of signals in cell is too big and its understanding and managing are very difficult for an inexperienced student.

However, there is another solution for beginner students. This solution requires only some basic knowledge in electronics to connect simple circuits for an infrared sensor, and in microcontroller programming, using a very easy language similar to BASIC, which controls every component in a mobile robot. All this knowledge is available for any second year student. The final success of the project was a measure of the understanding of the student and his ability to apply his knowledge.

The used AGV is home made, based on a Picaxe microcontroller [16]. Picaxe gives an IDE to program it from any PC. The program is sending to the microcontroller by serial port. The AGV has two wheels moved by two independent servomotors which are connected to two microcontroller outputs. It has a third free axe rotation wheel only to maintain the stability when robot moves.

On top of AGV there is a connection board. It is used to connect infrared sensors to microcontroller. These infrared sensors have binary outputs (1 or 0) which are connected to microcontroller inputs in order to obtain information about the working space. Two infrared sensors, with led and sensor in the same pack, are placed on left and right sides of AGV, and they are used to follow a black line with white background made on the floor. If one sensor detects black, it means that the robot is on the line and one motor is off to correct the path. At both ends of path, there is a perpendicular line that represents a parking zone. When both sensors detect black the robot stops, and waits for some actions. These actions are made by fix robots (robotic arms) in cell.

A container is placed on top of AGV to receive some material from the fix robot. The material is going to be transported from one place to another. A third sensor on top of AGV is used to detect presence or absence of material. In this, led and sensor are separated, but it works in same form than the others. On one side of the container an infrared led, and on the other side an infrared sensor are placed. When the sensor detects some signal means material is present, when not, there is not.

Another section of microcontroller program is made to wait for material. On one parking AGV waits some material is placed on it, and on the other, material removed from it. Both actions are made by fix robots. When one of these actions is made, AGV turns 180 degrees and follows the line to the other parking zone, completing the loop.

In this form, it is possible to use sensors in AGV to interact with fix robots in a manufacturing cell. The AGV with sensors follows a line made on the floor and detects when an object is placed on it in order to transport it to another place and waits till the object is removed from it. At this moment the

AGV returns to base position following the line, to pick up and transport another piece. All routines can be implemented, with same algorithm, to an industrial AGV.

In Fig. 1, the AGV and the black path with parking zones are showed. The path length and its form are defined by the user depending on the job. AGV can function correctly for any path length and form. Fig. 2 shows the interaction between two fix robots and the AGV in the manufacturing cell.

**Fig. 1.** AGV on black path and parking zones

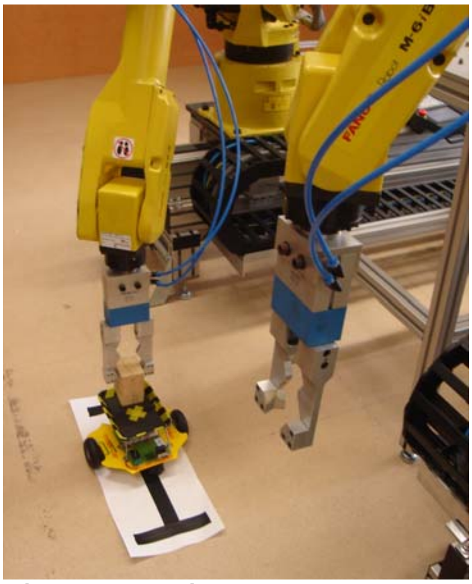

**Fig. 2.** Two fix robots interacting with AGV.

## 3. Two-armed Robot with Industrial Applications:

A large number of repetitive processes in the Mexican industrial sector are currently being performed using human labor. This makes it difficult to maintain standards, optimize the use of machines and boost the competitive advantage of Mexico. Rapid advances in this sector together with an increasing international pressure to enhance product quality and time of manufacture at lower costs require automation of these processes. Stamping or printing machines are very common in the plastic injection market. Every little plastic piece in the need of a stamp (markings) must go through a stamping machine. Given the low manufacturing costs in Mexico and other developing countries it is not always convenient to change to new more efficient mechanical machines. Automated machines through external (low cost) robots may be one of the best solutions due to the low costs and feasibility of external installation in the machine. In this project we have attempted to solve a similar problem with a local industry making control knobs for the kitchen stoves, using the ingenuity and originality of junior students. The industry currently utilizes manual techniques for the stamping of these knobs (the stamping machine itself is automatic). The manual labor is needed to feed the machine with unprinted knobs.

When the industrial problem was brought to our notice we started evaluating various “ready made” solutions, specifically robotic arms to perform the job. However, we faced two problems: the high cost of commercial systems, and unavailability of a robot which “optimally” solves this problem. Most of the robots are overkill for the type of problem and the user is supposed to pay the price of these extra, but useless degrees of freedom. We thus developed a new and unique robotic solution for them. The solution has been arrived at after a long process of evaluating alternatives and was motivated by the TRIZ methodology. One of the main ideas of this new robotic system is the utilization of two arms fixed at 90°. This separation helps the robot work twice as fast and to improve the printing and stamping of the plastic pieces while reducing the robot control and error detection work. We have also performed an economic analysis of the robot. It includes real data collected from the plant regarding the number of human operators and the quantity of parts made by each one of them. We then compare this with the use of our robotic solution and estimate the quantity of pieces produced by one to six robots of the same type. It shows a clear improvement in performance and the number of parts produced. Though the essential idea remains the same, several variations of this robot have been proposed by students including its CAD drawings, control system and mechanical structure. The first proposal and its model are shown in Fig. 3 and Fig. 4. A separate paper has already been published detailing the robot [17] which can be consulted for further details and references. Basic skills targeted in this project were design and innovation and were measured through the quality of final proposal.

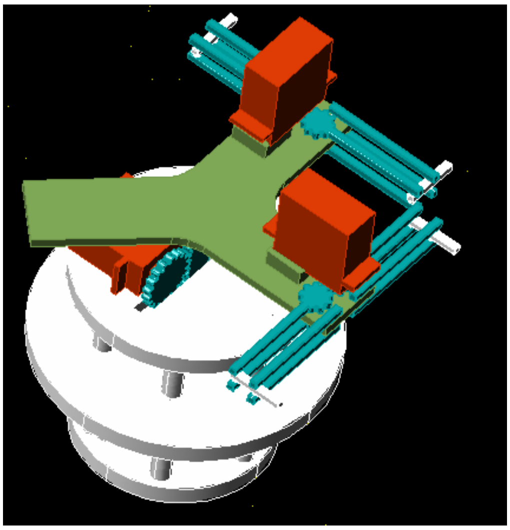

**Fig. 3**: The CAD Model **Fig. 4**: The plastic model

## 4. Crabot – the Cleaning Robot:

The project was designed to help students in learning Java programming and the subsumption robot control architecture. It essentially deals with the design and construction of an educational indoor cleaner robot named Crabot. Crabot is a LEGO based autonomous mobile robot, which represents the prototype of a real robot for house cleaning which requires a minimum of intelligence. Crabot is provided with necessary items for floor cleaning such as a small vacuum cleaner and a brush. The control system is based on the subsumption architecture with memory, and offers a repertoire of behaviors for navigation and cleaning. This kind of control system allows mixing real-time distributed control with behaviors triggered by robot sensors. Crabot was tested in an artificial world and in competition where its performance was very acceptable.

Students programmed the control architecture in leJOS [18], which is replacement firmware for the LEGO Mindstorms RCX brick, allowing programming the robot with Java. They employ a pair of bricks, one for cleaning and the other for navigation. As mentioned above, the developed control architecture was subsumption, based on the approach of Brooks [19]. They developed a set of actuation modules to sense relevant stimuli and produce a set of observable behaviors. The communication between bricks was carried out by messaging.

Considering Crabot was a robot for cleaning competition, some rules were dictated concerning robot dimension. Then, Crabot structure was a base of 25×30 $cm^2$ and a high of 25 cm. It weights 1.5 kg. The robot base was a differential model with two wheels controlled by independent motors at front and two fixed wheels at back for stability. Crabot had two touch sensors and two light sensors at front. Light sensor point out to the floor to detect garbage or the trash area. A couple of motors control the wheels, a third motor is employed to clean the garbage container and a fourth motor activates the brush situated at front of Crabot.

The garbage container was adapted as a slipper system to unload the garbage. The container has also a linear brush for cleaning and protection of the gages. Students adapted a small vacuum cleaner at back of Crabot. The vacuum cleaner was turning on and off automatically. Crabot is shown in Fig. 5.
We conclude that these kinds of projects are very attractive to students. They were very enthusiastic along the project development and during competition. Their abilities for Java programming were enhanced and their understanding for control architectures was improved. More details about Crabot can be found in [20].

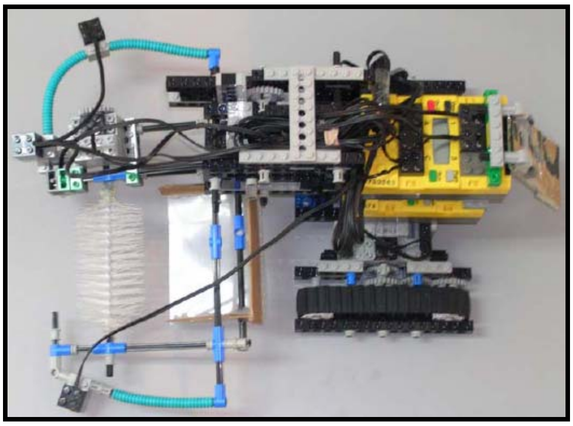

**Fig. 5**: Crabot in action**Fig. 6**. A variant of Crabot

## 5. Conclusions

We have found that the student motivation and hence retention in the program, increases when they can use their knowledge in various robotic projects. They understand their subject better and the level of satisfaction increases significantly.

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## References:

[1] LEGO Mindstorm web page: <http://mindstorms.lego.com/>
[2] Parallax, Inc., web page: <http://www.parallax.com/>
[3] B. A. Maxwell and L. A. Meeden, "Integrating Robotics Research with Undergraduate Education," IEEE Intelligent Systems, November/December 2000.
[4] E. Bilotta, P. Pantano and V. Talarico, "Learning Math Concepts by Visually Programming Robots," <galileo.cincom.unical.it/Pubblicazioni/editoria/period/Numeri/quad6htm/noe.pdf >
[5] D. J. Mehrl, ;. E. Parten, D. L. Vines, "Robots Enhance Engineering Education," 1997 Frontiers in Education Conference.
[6] K. S. Rawat, and G. H. Massiha, "A Hands-On Laboratory Based Approach to Undergraduate Robotics Education," Proceedings of the 2004 IEEE International Conference on Robotics and Automation, New Orleans, LA. April 2004.
[7] Wang, E.; Wang, R., "Using LEGOs and RoboLab (LabVIEW) with elementary school children," 31st Annual Frontiers in Education Conference, 2001. Volume 1, 10-13 Oct. 2001 Page(s):T2E - T11 vol.1.
[8] Mukai, H.; McGregor, N., "Robot control instruction for eighth graders," Control Systems Magazine, IEEE, Volume 24, Issue 5, Oct. 2004 Page(s):20 – 23.
[9] K. Nagai, "Learning while doing: practical robotics education," Robotics & Automation Magazine, IEEE, Volume 8, Issue 2, June 2001 Page(s):39 – 43.

[10] Robinette, M.F.; Manseur, R., “Robot-Draw, an Internet-based visualization tool for robotics education,” IEEE Transactions on Education, Volume 44, Issue 1, Feb 2001 Page(s):29 – 34.

[11] Dias, M.B.; Mills-Tettey, G.A.; Nanayakkara, T., “Robotics, Education, and Sustainable Development,” Proceedings of the 2005 IEEE International Conference on Robotics and Automation, 2005, 18-22 April 2005 Page(s):4248 - 4253

[12 ] Dong-Il Kim; Jin-Ki Kim; Hak-Kyung Sung; Sungkwun Kim , “Sensor-based navigation control and calibration of a wafer-handling mobile robot,” Industry Applications Conference, 1995. Thirtieth IAS Annual Meeting, IAS '95., Conference Record of the 1995 IEEE, Volume 3, 8-12 Oct. 1995 Page(s):1922 - 1929 vol.3.

[13] Huosheng Hu; Dongbing Gu, “Landmark-based navigation of mobile robots in manufacturing,” Proceedings of the 1999 7th IEEE International Conference on Emerging Technologies and Factory Automation, 1999. Volume 1, 18-21 Oct. 1999 Page(s):121 - 128 vol.1

[14] Doty, K.L.; Van Aken, R.E., “Swarm robot materials handling paradigm for a manufacturing workcell,” Proceedings of the 1993 IEEE International Conference on Robotics and Automation, 1993. 2-6 May 1993 Page(s):778 - 782 vol.1.

[15] Murphy, R.R.; Arking, R.C., “Autonomous mobile robots in flexible manufacturing systems,” Proceedings of the Fourth Conference on Artificial Intelligence Applications, 1988. 14-18 March 1988 Page(s):412 – 414.

[16] Picaxe microcontrollers, web page: <http://www.rev-ed.co.uk/picaxe/>

[17] Eduardo Manzur Servín and Yousuf Muhammad Ali, “TRIZ Motivated Design of a Two-Armed Manipulator for the Stamping Industry.” 1$^{st}$ Iberian & Latin American Conference on Technological Innovation, Puebla, Mexico, 4-7 September 2006.

[18] <http://lejos.sourceforge.net/>

[19] Rodney A. Brooks. “A robust layered control system for a mobile robot”. *IEEE Journal of Robotics and Automation*, 2(1):14–23, March 1986.

[20] Rodrigo Montúfar-Chaveznava and Yazid Fernández, Crabot: Educational Robot Prototype for Cleaning. Proceeedings of 12th Portuguese Conference on Artificial Intelligence (EPIA 2005): Covilha, Portugal, 5-8 de December 2005, pp. 266-271.