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Experience on Design of Tests in Robotics by the Students

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ABSTRACT: *The aim of this paper is to describe the experience developed on the Robotics laboratory of Antonio de Nebrija University about the learning of the students in the fields of Robotics and Programming.*

The experience was focused to design several tests to build wheeled robots abled to pass certain tests. The behaviour of the robots is based on the trails devised by the students themselves. Thus the students get an improvement about the handling of sensors and algorithmic programming.

There were two kind of students, one of them came from the Electronic engineering and the other one came from the Computer engineering; both of them belonged to the Polytechnical School. Despite of the final objectives were the same to all the students, the designed tests and the way to achieve the objectives were different enough. The Electronic engineering students tests were based on the distribution of the sensors and the study of the physical structure of the robots; on the other hand the Computer engineering student tests were focused on the microprocessor programming, according their knowledge.

In order to encourage to the students, the experience was presented like a contest named NEBBOT'03.

The experience and how it was launched is described at the beginning of this paper. Later, the components and the basic algorithms are showed. After that, it is explained the evolution of the investment of the students in the laboratory. Finally several conclusions about the whole experiment are pointed out.

1 INTRODUCTION

Robotics in Antonio de Nebrija University is an optative subject if you study Computer engineering or a troncal subject in case of studying Electronic engineering. It was wanted to do a simple experiment: the aim was to know how the students were able to solve several Robotics problems (the same for everyone) in spite of having different previous knowledgement. In order to do that, a contest were prepared. In it, the student groups had to funfill several requirements to participate (the same for all the groups). The objective was to know which groups (Computer engineering students or Electronic engineering students) were able to give the optimal solution.

2 EXPERIMENT SURROUNDINGS

The own nature of Robotics clearly raises two differentiated aspects:

- A physical aspect, in which is included everything in relation with the robot assembly (microprocessors, electronic material, etc.). In case of Robotics students, the Electronic engineering ones are the indicated to obtain the best from this aspect.
- A logical aspect, in which is included everything relationed with the robot programming that was previously assembled. In this case, the indicated students to obtain the best from this aspect were the Computer engineering ones.

Robotics subject in Antonio de Nebrija University is based on teaching a teorical knowledge and the practise of that knowledge in the laboratory. To do that, there are several Robotic kits with certain functionalities. The kit kernel is a microcontroller. This one is a Motorola 68HC11, that have the ability of being powerful and easy to use. It also allows to be conected to several peripheral, as power stages, servomotors and others. The kit programming can be done using C programming language (which is not recommendable due to the fact that the programs use to be large and the memory is small) or Motorola assembler. This last option was the one that was used along the whole experience.

When the robots were assembled, a set of sensors and additional peripherals were used. The main interest of using them were to obtain information from the robot surround. Because of this, information about the nature and functionality of that elements was given to the students. The way in which they had to integrate all the elements was indicated in a brief form too.

The Robotic subject main objective is to get the best results with the material that the students had at the laboratory. To obtain it, it was decided to mask the experience under a "Course – Contest": thus, the students were teached for two days. In these two days they basically learnt how to build and program their own robots. After that, the groups had other three days to develop a set of tests to verify that the robot did what it had to do. This was necessary to assure that the robot was able to surpass the contest. The contest had two tests named Tracking and Labyrinth:

- In Tracking test the robot had to follow a black line on a white surface. The robots could not leave the black line anyway. The road could have bifurcations. The direction that the robots had to take was specified by marks. They were placed beside the road: if the mark was placed on the right hand (over 20 cms before the bifurcation), the robot had to turn right in the intersection. If the mark was placed on the left hand, it had to turn left.
- The Labyrinth test consisted in getting outside of a laberyrinth made by several walls. The robot could use the black lines placed in the center of each possible road inside the labyrinth, which form was previously showed to the students.

In this way NEBBOT'03 was born. A contest in which Computer and Electronic engineering students could participate. Every student had to apply his or her own knowledge to optimize everything in order to win the contest. The winners were allowed to participate under the name of Antonio de Nebrija University in the national Robotic contest HISPABOT'03.

All this, and remarking something already exposed, to verify how students with different nature confronted similar problems in Robotics from clearly different previous knowledge.

3 THE COURSE – CONTEST

Several teachers from the Polytechnic School of Antonio de Nebrija University organized the course-contest. They were four teachers: two Computer engineering teachers, one Physics teacher and one Electronic engineering teacher, and the students were twenty five divided into ten groups. Each group was formed by two or three people. There were two groups of students from Electronic engineering and eight from Computer engineering.

The course-contest lasted five days. Along the first two days the principles of Robotics were explained: the structure of the robots, the pieces and how to construct them, the actuators, the electronic components, the electronic boards and the 68HC11 microcontroller and its programming in assembly language. The following two days were dedicated to work at the laboratory. The students selected the pieces, constructed the robots, programmed the microcontroller and made the tests to the robot in order to surpass the competition tests. The last day, the contest took place. The robots had to surpass two tests as related before.

First of all, the basis of the robot that students had to manage and its mechanical structure and components were explained. This was a semi-autonomous wheeled robot with a simple structure. It had three wheels: two traction wheels and one support wheel. There were two servomotors associated to the axes of the traction wheels which made turn on the wheels so that the robot could advance towards. The robot was also able to operate some curve turning on right one traction wheel and the other one turning on left. The support wheel was used to maintain raised the robot. Students had to learn about servomotors, its operatibility, the assembly to the wheels, etc.

The robot had several infrared sensors which were able to detect black or white. Placing suitably the sensors, the robot was able to follow a black lined way. Students had to learn about infrared sensor, its technology, operation and connection. The robot had two boards, one of them to control the servos and sensors, and the other one had the 68HC11 microcontroller which was the heart of the robot. Programming suitably the microcontroller was possible to control the movements and the state of the robot. Students had to learn about a microcontroller, its pins and ports, its memory structure, the assembler language and to implement the programs.

All the electronic components were powered by a battery. Students had to learn to connect the battery to the boards and besides to assure that components were connected and powered.

The robot had a chassis made by Lego pieces in which the boards, battery, wheeled axes and the rest of components were joined in order to build the robot's body. Students had to learn to select the suitable pieces and join them to get a solid structure.

The last day was dedicated to the contest which is mentioned above. Each group had to register its robot with a name. Then, the order in which the robots had to try surpass the tests was selected at random. The list was made and the first test, tracking test, began. On turn each group placed the robot on the start point. The time to get the finish was measured. Not all robots reached the finish without leave the black line. Some robots left the way sometimes because a bad sensor placement, sometimes because a bad programming, sometimes because the physical design implied excessive speed (very big wheels) or all the opposite, too slow, caused the heavy or complicated decoration incorporated to the structure of the robot. Seven groups which arrived at the goal were ordered according to the spent time to cross the way.

After that, there was enough time to prepare the robots to the second test: labyrinth test. The map of the labyrinth was showed short time before the beginning of the test, in order to give same advantage to all the groups. Each robot had to run over the labyrinth and get the exit in the minimum time. Only three robots got the exit. Some of the others begun to run the way repeating some stretchs and when spent a limitned time they were eliminated. Other ones did not work well and were not able to advance across the labyrinth.

Then the robots were pointed evaluating the two tests and the champion was the group that spent the minimum time surpassing the tests.

4 STUDENTS' EXPERIENCE

4.1 Electronic engineering students

The students coming from Electronic engineering focused their efforts to improve the physical characteristics onto the robot rather than to optimize the algorithmic programming. They used the basic programs provided to get the objectives. So, they had to compensate the deficiency on programming with improvements on the structure, stability and velocity of the robots.

Attending to the labyrinth test, some groups of students wanted to change the servomotors to stepper motors to get better control on the rounds, though finally it was not possible. It was not allowed because the advantage from the other groups would be so higher than the experiment would be useless.

In order to get more speed, almost all the groups changed their wheels. The idea was to get more lineal velocity with greater radius and equal angular velocity. To increase the radius in the wheels became heavier robots and more friction on the surface than before, so the speed gain was not so great as it was expected. Because of this, substantial improvements in the advance were not obtained. It was necessary a commitment between speed and size. The best results were obtained using fine wheels with long radius.

The students got great speed without increasing the weight. The robots were tested on different surfaces just taking the time to cover a distance.

To increase the radius of the wheels caused that the robot moved away from the ground and lost stability. Consequently, the measurements from the sensors were not precise enough, even wrong. Getting better sensors made the robot more expensive so just a few groups decided to get another kind of sensors. The most common solution was to separate the sensors from the main body of the robot and to approach them to the ground. Tests were made on plane surfaces which had a black line drawn on it. The line had straight sections and sections with curves of different angles. The robots must to follow the black line. Initially the results were really bad, but when the sensors were nearer to the ground the results were quite better. Despite of this, in closest angles, sometimes the sensors did not get good data.

More difficulties appeared. Pitch and yaw were not rightly corrected. There were two solutions to solve this problem, first of them was to set two new sensors in to the robot, so there was more surface to be covered to detect the black line. This solution made that the algorithmic programming were changed to consider these new data. The other solution was to make the robot heavier adding some weights. The consequence was to lost speed. Depending on the weights distributions, the sensors were set at the back of the robot or in the frontal part. To get more speed, the way to get more weight was to add more batteries, so the robot was heavier but it had more power to supply the servomotors. It meant more power to the servomotors and of course more linear velocity. The combination of these two systems, more weight and more sensors, obtained the best results. Surpassing finally to the rest of robots.

The last point was how to recognize the clues along the black line to select the best way. It was necessary to add two sensors more and to change the program so, most of groups of Electronic engineering rejected this option. They though that to improve the speed would compensate the wasted time due to not to go by the fastest way. At the end, that was right but the results were not so good as they could be adding the sensors.

4.2 Computer engineering students

Once known which were the elemens of the robot, the students of Computer engineering setted out to build a trustworthy and versatile robot in not more than four days.

The Computer engineering groups approached the experiment with basic knowledge of electronic technology, but with a great ability developing software. Over other aspects, the Computer engineering in Spain study mainly the software programs implementation.

The experiment could be divided in several stages in which partial goals were covered and that allowed to advance from the beginning until the objective. These stages were the following ones:

- Physical robot construction
- Boards of control, servomotors and sensors verification
    - Trainer Way
    - Autonomous Way
- Development of an optimal program for the tests

In the physical robot construction, the Computer engineering students did not work more than one hour. They did not worry to optimize the material provided by. They attacked the problem by the "brute force" method. They joined all the pieces one on the other, put the servomotors on both sides of the physical structure, placed batterybox and set four sensors in the frontal part of the robot.

When the robot structure was built, the verification for the componentes and its correct operation was made through one program named "CT293 Control". With this program and the connection (RS232 - DB9-TLF) between PC and control board, the students were able to connect to board CT6811 where the 68HC11 microprocessor was palced. In this program, some flags verifies the operation of the sensors. Moreover, with the keyboard controls (up, down, left and right keys), it is possible to verify the servos and probe their correct operating functions.

To verify the "autonomous way" of the robot, the students loaded in the microprocessor's EEPROM one first program that use the sensors signals to follow the way drawn up with a black line.

The work at this moment acquired great dimensions. The students had to develop an assembler code which was able to solve the two tests in which the robots were going to be put under. On one hand, the test of tracking and on the other one, the test of the labyrinth.

The algorithm used in the test of tracking was extremely simple. Thanks to the signals received by the four sensors placed in the front part of the robot, the signal sent to the servomotors was one or another one (turn left or turn right). In this way the program included all the posibilities which the robot could be found during the test.

For the test of the labyrinth, the students developed one first algorithm that before the bifurcations forced the robot to turn always to the right. In this one way, the robot was able to leave the labyrinth invariably, but used many time to do it.

With the purpose of optimizing the operation of the robot in this test, the students were decided to use a data structure that stored in one matrix the squares of the labyrinth. With this another algorithm the robot was able to have stored all the labyrinth inside its microprocessor memory. Thanks to this one solution, the students were able to detect which was the shortest way between two points of the labyrinth. Once established the way for coming out from the labyrinth, the microprocessor only had to send the right signals to the servos so that it executed this layout. The students had developed an efficient way to solve the problem of the labyrinth.

5 CONCLUSIONS

Looking at the students, we can point out:

- It is very difficult to get that the students get knowledge from other areas differents of their own areas. So, Electronic engineering students refused to improve the algorithmic programming to optimize the computational operations and, on the other hand, Computer engineering students do not use to change the physical structure of the robots to improve the mechanical response.
- The efficiency of the students is considerably better if the context to work is nice to them. Though, as we exposed before, the progress is made into their own knowledge areas, and they not explore the other areas to improve their knowledge on them. They explore new possibilities, improvements and advances there where they are more secure. Just one idea: they learn better.
- The experience improves the subject of Robotic. The range of contents is wider than last years. The students are more satisfied than just studying teorical concepts and with a few hours in the laboratory. That is because teorical concepts can be immediately applied at the laboratory in real problems.
- Furthermore, despite of the increase of work, teachers find more instruments and new stages to teach the concepts and it is more grateful than the traditional class.

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