NEM PATHS IN ENGINEERING EDUCATION: ROBOTICS

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Abstract. *In this paper is described the deployment of robotics systems in education in order to strengthen creative, learning, design, cooperative, analyses and solving problem skills. Also it is presented robotics as an important method to learn and verify computational models. It is illustrated some approaches that have been made in this matter and it is framed inside them the Educative Platform TEAC^{2}H-RI (Technology, Engineering And sCience eduCation through Human-Robot Interaction), which is currently being developed by the Universidad Nacional de Colombia. TEAC^{2}H-RI will be implemented in the Senior High-School students of the Colombian educational system level.*

Keywords*: Educational Robotics, Computer Science, Learning, Creativity, Design, Human-Robot Interaction*

1. INTRODUCTION

Currently the World is going through a crucial period in its history, when it has to face challenges which threaten the welfare of the human beings. Some of them are: global warming, greenhouse effects, epidemic, pandemics, natural resources scarcity, political stability, overpopulation, pollution, unemployment, besides others (UN Millennium, 2005). Furthermore, the vertiginous technological development obtained in the last years has required of skilled individuals to face the market's demands. The above exposed factors impose a strong pressure over the education system and require it to evolve. The evolve paradigm must be focused on strengthening the design, researching, creativity and cooperative skills.

In the developed countries this concern has been addressed through different approaches, being one of the most relevant the human-robot interaction. It is used in the teaching of electronics, mechanics, mathematics, informatics among other engineering themes. Also, it is implemented to strength creativity, cooperative, analyses, solving problems and design skills in the learners. Although, the efforts made by the Latin American region in this matter are very few despite the fact, that it is one of the most needed regions of these solutions. The roots of this problem are the short economical resources, the technological backwardness and the relevance assigned to the research (UN Millennium, 2005).

This paper is organized as follows: Section II briefly reviews the educational robotics. Section III presents some efforts to implement educational robotics in countries with emerging economies. Section IV describes the methodology proposed. Finally, section five presents the conclusions and future work.

2. EDUCATIONAL ROBOTICS

One of the most important moments in the history of the education was the XIX century when different approaches proposed the switch from the traditional passive to an active educational paradigm. In the traditional model the two main roles are active and passive which are assigned to the teacher and the learner, respectively. Where, the knowledge was assumed like a fluid which can be transferred from its source (teacher) to its goal (learner). (Papert, 1990)

Later, in the XX century, two of the most important approaches were the constructivist theory of the Swiss psychologist Jean Piaget and the constructionism pedagogic developed by the south African mathematician Seymour Papert. The first one, claim that the knowledge is not transmitted but is built, i.e., it is created actively in the learner's mind (Piaget, and Inhelder, 1966). The pedagogic of the second is built upon the previous theory and because of that it also claimed that the knowledge is built actively in the mind's learner, but it goes far beyond saying that it is also necessary that the individual create something tangible, an element outside from his mind which additionally brings him a personal meaning. (Chiou, 2004). This last pedagogic theory, was the foundation of the most important approaches in educational robotics.

Some of the most important educational robotics products are LEGO Mindstorms, Logo, Fischertechnik (Chiou, 2004)., Pioneer, K-Team, IroRobot and Handy Board (Anderson et al., 2007), (Barrera et al., 2005), (Martin, 2001). The first three not only are used in high school but also like toys. On the other hand, the last five are implemented in the industry, in high school and in university. They have an important relevance in computer science but also in the engineering. It encourages the verification of algorithms, a deeply understanding of programming and the developing of many cognitive skills (Blank D., 2006).

In all of the examples presented above, LEGO Minstorms and Fischertechnik are the widely used in the World due to its comparative low cost with regard to the other options and the didactical resources available. The philosophy of both of them is very similar for the numerous construction blocks which being assembly permit to shape various prototypes. One of them, called RoboExplorer, can be seen in the figure 1. It is made by Fischertecnik. It is compound of a NTC resistor, a photoresistor, an ultrasonic distance sensor, an infrared and color sensor and a specially developed track sensor. Two power motors and a crawler drive are in charge of the movement. Also, it contains the ROBO interface, ROBO Pro software and rechargeable battery set (Fischertechnik, 2009)

Figure 1. Fischertechnik: Robo Explorer (Fischertechnik, 2009)

3. EDUCATIONAL ROBOTICS IN EMERGING ECONOMIES

Some of the most important approaches in educational robotics implemented in emerging economies are the following.
In Qatar and Ghana the Carnegie Mellon University joint with some high education institutions from these regions imparted a course in autonomous robots. The purpose was to strengthen the creativity and the knowledge on computer science of the student. The hardware used was the MIT Handy Board and the LEGO bricks, while the software was the Interactive C. At the end of the courses the conclusion was that the implementation of robots in Computer Science students really fulfilled the desired objectives and besides it, the interest for research and technology topics was increased. Nevertheless, it was observed that the interaction between the individuals of each group of work changes depending on cultural conditions. This fact must be kept in mind when the course is designed (Dias M. et al., 2007).

In Costa Rica the Massachussets Institute of Technology (MIT) worked in a rural school. The hardware and software used were the LEGO Mindstorms and the Yellow Brick Logo (or RCX Logo software), respectively. The obtained results permitted to conclude that the use of robots in primary school strength creativity, learning and problem solving skills. (Urrea, 2001).

As was illustrated in the previous paragraphs, it exists a lot of educational robotic kits, however, the fact that they where worked out in countries with socio-economical characteristics far different from the Latin American reality, made these tools very unsuitable for this environment. Additionally, its costs are unreachable for the most of the educational institutions in these countries. Because of that it is necessary to carry out a deeper assessment of the Latin American reality and provide an indigenous solution adapted to the region necessities (UN Millennium, 2005). From de education perspective it is important to mention that this kits have a limited number of pieces, issue that shape the mind of the learner to develop some prototypes. In the technical field, one of their most important weaknesses is the fact that each brick has a specific equation that can not be modified by the user (Zuckerman and Resnick, 2003). This last factor restricts the learning and the creativity improvement.

4. PROPOSED METHOD

On the 2006 the Research and Development Group on Artificial Intelligence (Grupo de Investigación y Desarrollo en Inteligencia Artificial) (GIDIA) of the Universidad Nacional de Colombia built an intelligent swarm system with the purpose of collaborative navigation through structured environment (figure 2). This project was called SMART, i.e. Multi-Agent Robotic System to the Collaborative Navigation (Sistema Multi-Agente Robótico para la Navegación Colaborativa). After that, it was created the Research Group on Artificial Intelligence in Education of the same institution. This group is focused on the deployment of robotics with pedagogic aims. On the 2008, this last group generated the research project called Educational Robotics: Intelligent Machine in Education, where all the constraints mentioned above were satisfied through the development of the Multi-Agent Robotic System TEAC^{2}H-RI (Technology, Engineering And sCience eduCation through Human-Robot Interaction) which is focused to be implemented in Senior High School students of the *Área Metropolitana de Medellín*.

Fig 2. SMART: Multi-Agent Robotic System to the Collaborative Navigation in structured environments; developed by GIDIA: Research and Development Group on Artificial Intelligence (Grupo de Investigación y Desarrollo en Inteligencia Artificial) (GIDIA) of the Universidad Nacional de Colombia

TEAC^{2}H-RI (Technology, Engineering And sCience eduCation through Human-Robot Interaction) is formed by four robotic agents, i.e. three sons and one mother. It is a hybrid system for its distributed and centralized characteristics. It is distributed because the son-robots may interact among them, and it is centralized because its mother can do the group leader role (Fong et al., 2003).

It is important to claim that the Human-robot interaction is also presented when each agent, by means of four LEDs and one buzzer, produce light and sound signals which indicate the robot's state and let to take amending actions by the user (Fong et al., 2003).

Every agent navigate the environment and avoid the obstacles, but only the mother-agent can send or receive data toward or coming from a PC, either by a radio link or a cable. The navigation of the agent could be done in path follower or in the obstacles avoidance mode with and without touching them.

This Multi-Agent robotic system will be employed in different sessions with the high school students. The up limit of students per session will be 16, uniformly distributed in four groups, with a robot assigned for each group. This work methodology with the kit TEAC^{2}H-RI promotes in each learner the cooperation with the other group members, i.e. everyone in the group will work on the behalf of the others. Furthermore, each group will work for its best, but also for the other groups' welfare. The purpose of these two behaviours is the teamwork strengthening inside the groups and among them and this is the fundamental enterprise and research group model.

4.1. Sensors

Most of the educational robotic systems, used in high school students, are closed i.e. they forbid the use of devices that not belong to the kit. This fact obstructs the acquisition of replacements and the design of new devices. On the other hand, TEAC^{2}H-RI (Technology, Engineering And sCience eduCation through Human-Robot Interaction) is compatible with additional accessories and as a result it is more adaptable to other technologies. The kit comes with five different sensors for each agent. Over them many experiments and modifications can be done. Moreover, the kit permits to the learner the creation of three additional sensors. The provided sensors let to the robot to avoid obstacles with/without touching them (IR and touch sensor), follow tracks (IR sensor), detect light intensity (photoresistence), navigate based on claps, sense temperature (NTC resistence) and measure the distance (ultrasound sensor) (Jimenéz and González, 2008).

Figure 3. Second Step in the construction of the TEAC2H-RI kit. Base structure assembly.

4.2. Mechanical Design

The chassis of both robots is very similar; its geometry is 23 cm long, 14 cm wide and 10 cm high. The chassis consists of a first level plate where the motors board is and a second level where the main board is. The acrylic plates of each level contain Velcro ® in their contour to vary the position of each sensor and explore its operation depending on the position. The design of the chassis, which can be assemble or disassemble, makes it ideal for experimentation and the understanding of important physics and mathematics concepts. For instance, the distance from the motors to the center of mass, the position of the sensors on the plate or the spatial distribution of mass in the system, introduce important concepts like center of mass, torque, wave interference, and others. An additional advantage of TEAC^{2}H-RI's pieces is that they are inexpensive and easy to be purchased in the Colombian and Latin American market, and fact that is not common in the other kits. There are some steps in the assembly in figure 4.

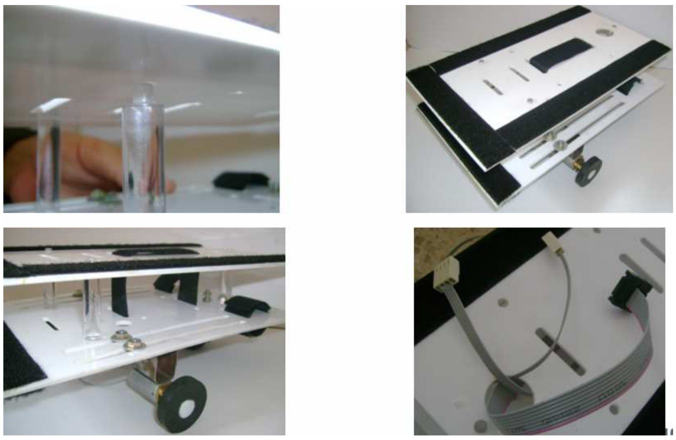

Figure 4. Second step in the construction of the TEAC2H-RI kit. Chassis assembly.

4.3. Programming Language

One of the most important uses of the TEAC^{2}H-RI kit is the education and the validation of algorithms through the Human-Robot interaction. In the first phase of the project implementation, will be use the programming language CodeWarrior® of the Metrowerks Company which is supported in C. However, is been considering to develop a more user-friendly algorithm does not require knowledge in C for the kit interaction and also provide an introduction to the programming world.

4.4. Learning Guide

The learning guide includes topics in physics, mathematics, electronics, algorithms, and artificial intelligence which can be learned by the agents. This is one of the most careful points of the project, because it requires an element with the appropriate terminology, explicit concepts and precise examples to capture the attention of the students. Some authors assert that a poor attention to this step can create or increase the phobia towards science subjects (Chiou, 2004). The robot assembly process is shown in figures 3-5.

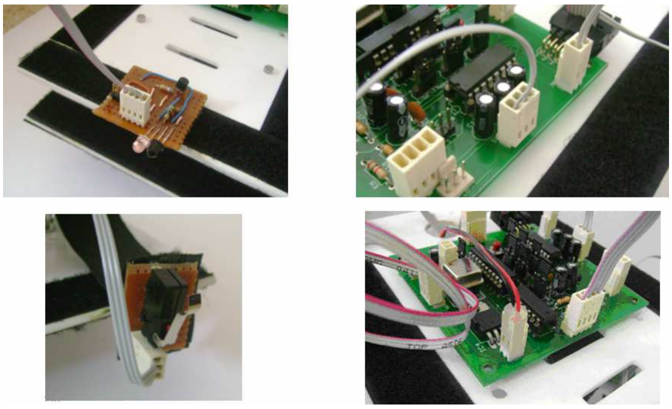

Figure 5. Third step in the TEAC2H-RI robot assembly: Electronic components.

5. EDUCATIONAL ROBOTICS IN SCHOOLS

In the first stage of implementation of TEAC^{2}H-RI, the project will involve the Senior High School students of the *Área Metropolitana del Valle de Aburrá*, mainly in the schools near to *Facultad de Minas of the Universidad Nacional de Colombia*, in the neighborhood of *Robledo*.

Ten TEAC^{2}H-RI kits, i.e. forty robots, will be shared between the ten schools chosen. In order to receive that kit, the school must meet the minimum requirement of a computers classroom; otherwise the university will assign a computers classroom for that purpose. The course duration is 5 weeks, with 4 hours per week.

The first workshop will be given to the teachers in order to gain their cooperation in this education model. Based on the market demands and the global challenges that the education is facing today, it will be explained to teachers the reason for change the educational paradigm. Then, it will be exposed the Constructivist Philosophy of Piaget, the Meaningful Learning Theory of Ausubel and the Constructionism of Papert, in order to demonstrate that the traditional passive role of the student has to change into a new active role in which he builds his own knowledge from the experience and interaction with objects, the learning of significant information and the creation of physical objects. Later the teachers will have the opportunity to see the functionalities of the prototype in order to change the technophobic or premises against robotics (Urrea, 2001) Finally, it is shown that the active role of students in their learning process can be done through the human-robot interaction.

The second workshop will focus on increasing the student's interest in science themes. This step is very important for the success of the course. Initially, the students will see an interesting film related to robotics. Then, they will be induced to observe and analyze the kit performance. After that, groups of four students will be assigned a TEAC^{2}H-RI robot and a tutor. The interaction with the robots will bring a special meaning to the students (Ausubel, 1963) and as a consequence a better understanding of the laws that govern it.

When the learner as a result of interaction with the robot has understood the principles and equations governing the system, he can modify it to get new results and understand concepts such as: overlapping lobes, angular momentum, center of mass, friction, electrical resistance, and others. This is the third workshop (Wedeward, 2001).

In the next workshop, each student will have the freedom and the tools to develop new prototypes, no necessarily related with robotics but with the themes addressed in the workshops in order to furthermore clarify and strengthen the learned concepts and the creative skills. The tutor will not impose his ideas to the learner instead he will be a support to the student learning process, without restricting his autonomy to explore, experiment and create.

During the fifth workshop, the students will be asked about how did they feel working in the final design of the project? Which are the main attributes of the final design? What was their level of satisfaction? In which industry the concepts acquired are applied? Why do they choose that design? and other similar questions, in order to improve the communication skills in learners (Dias et al., 2007). The reason for using this method is that the student is interested to sharing with others that he likes (Acuña, 2006).

Finally, the groups will be encouraged to constructively criticize each other, identifying strengths and limitations of the prototype, in order to improve the capacity of the students to accept different points of view, and thus expand their sense of community (Wedeward, 2001).

6. CONCLUSIONS AND FUTURE WORK

The cost of production is around $65US per robot which is very low compared to other alternatives of the market.
The robotic systems are an excellent tool for the performance verification of the computer simulations because they are evaluated under real environmental conditions.

The employment of educational robotics kits developed inside the Latin American region are better adapted to the reality than those imported from developed countries. Because of that, it is necessary that the university, private sector and government joint efforts to create new indigenous alternatives to fortify the creativity, learning, design and teamwork skills.

The social group that will be affected by TEAC^{2}H-RI is the Senior High School students from the *Área Metropolitana del Valle de Aburrá*, although, it is also considered the development of new kits that could be implemented in all educational levels, i.e. from Elementary School to undergraduate studies. But no only in the *Área Metropolitana del Valle de Aburrá* but also in other regions of the Antioquian department, the country and the Latin American region. In particular, it is important to mention that in future works also the urban regions will be addressed, because the desired result on the educative, productive and social sectors needs to involve all the productive regions.

It will be sought in future projects to develop new programming language for dummies in computer science. It will be made in order to facilitate the interaction between the learner and the TEAC^{2}H-RI kit, to increase the interest in these topics and to introduce the learners to the programming world.

While the currently kit allow the Human-Robot interaction, it is consider necessary to embed new sensors, software and new design mechanical models to provide new improvements in this aspect. For example the kit based on the learner or group characteristics will adapt the learning process. (Fong et al., 2003)

The technological tool, the TEAC^{2}H-RI kit in our case, can not be seen as the panacea to solve all the educational problems in Latin American, because the most important issue is the improvement of the joint work between Goverment-High School-University-Private Sector (UN Millennium, 2005) (Papert S., 1990). This new model required a greater effort and commitment but it deserves to be done because the result will be better.

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