INTEGRATED LEARNING PROCESSES BASED IN LEGO MINDSTORM AND PETRI NET

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Abstract. *In the most graduation engineering courses is unusual to find students that make contact with the pratice experience of automation area and the mechatronic devices involved, since it was necessary to invest in high cost equipment to teaching these topics. Besides, the teaching of advanced topics in this area requires the application of new methods in order to motivate and involve the students in the learning process. In this sense, LEGO platform appears as a simple, flexible, attractive and educational solution to solve the referred challenge in several domains of knowledge. Thus, this paper describes a method and experience of the introduction of the educational LEGO Mindstorms platform at high-degree studies to support the learning of mobile robotics. An interdisciplinary subject, combining and integrating different areas of knowledge, such as mathematics, physics, mechanics, electronics, control, and computer programming. The process is based on Petri net (PN) and its extension - PFS (Production Flow Schema) is used to structure the development of components' models and presentation of the proposed procedure. Indeed, meta-disciplinary skills such as team and presentation competences, critical faculties, time management and project management competences are trained. These integrated learning processes play a decisive role for innovative ability and sustainability in an enterprise because corresponds to the demands of work environments that students will encounter during their future professional careers.*

Keywords*: Robotic Mobile, Control System, Education, Petri Net, LEGO Mindstorm*

1. INTRODUCTION

The production systems (PSs) have undergone great changes due to advances of mechatronic systems, communication networks and work organization methods, allied to the crescent competitiveness and the need for efficient services. Thereby, PSs evolved to become more flexible under different conditions such as production volume, product type and nature of the resources involved (Silva et al., 2011). The flexibility of PS can be understood as ease founded to adapt the production process in way to improve the quality of products or services and the ability to customize items, i.e., materials and / or information to be produced or processed.

The flexible production systems (FPSs). were created to meet the current requirements above. But, the understanding of these FPS is considered a complex task because it involves the modeling of several heterogeneous subsystems that interact together to perform simultaneous processes which can share the same resources, and involving large numbers of variables, in considerable size and in dynamic nature; The modeling of FPS also must be consider the social capacity of the system, i.e., the consideration of the human interaction on processes, as designer, user and operator, also must be considered. In other words, although there are many mechatronic technology for developing the applications of the FPSs, the appropriate use of technology also requires upgrading of human knowledge. (Silva et al. 2010a).

Thus, the area of automation and control is based on modeling of systems of different nature, analyzing their dynamic behavior, and using the control theory to calculate the parameters of a controller that makes the system evolve as desired and in a manner adaptive to changing environment . But, for a proper automation of a system is necessary to have an overview of the production process, which does the professionals in the area, to use informations which relate different areas of knowledge, as is the case of engineering and computer science. The knowledge of automation and control has your applications in process industry, such as in chemical, petrochemical, food, textile, pulp and sanitation. It is necessary to control the behavior of the variables that affect the quality of products according to established standards along route in a production plant. Moreover, all branches of discrete automation, as the manufacturing, can benefit of the advanced techniques of control system modeling. Among the applications in this industry finds industrial robotics, machining parts, and motor control. Thus, it can be argued that the control technology and automation has generated a large increase in competitiveness in several areas while the automation of processes has significantly increased productivity and product quality.

Even with all the importance of automated equipment and process control in the evolution of the PS, is a major difficulty in teaching this theme in universities, because the disciplines that surround them are allocated at the end of engineering courses and to require prior knowledge discipline such as electrical engineering and electronics.

Another great challenge faced in universities is the difficulty of teaching in some areas of knowledge where the low level of student learning has been the subject of several surveys and studies that demonstrate this problem and propose alternative solutions to traditional methods. Some statistical studies related to academic success show worrying signs in some key areas of learning for human development, such as physics, mathematics and engineering. In fact, it is essential to analysis and proposal of new teaching methods used in this area, to motivate students during their learning process and therefore this subject is considered a matter of great importance.

2. MOBILE ROBOTIC

Mobile robotic is an interdisciplinary subject, which combines and integrates different areas of knowledge such as mathematics, physics, mechanics, electronics, control and automation, computer programming, artificial vision and artificial intelligence. By definition an autonomous mobile robot has the capacity of mobility and executes its own decision using the answer given by the environment. The autonomous mobile robotic encompasses a significant number of complex tasks, such as perception, localization, navigation and trajectory planning (DUDEK & JENKIN, 2000).

According to PIO et al, 2006, the sensorial perception aim to response questions like ‘where am I?’, and ‘which environment am I placed in?’, and to collect information to determinate the location of the vehicle and the distance to the obstacle. He is compound by three principal subtasks: environment mapping and modeling, trajectory planning, selection and orientation. In certain situation, additional subtasks, such as cooperation which other anonymous entity, can de added. The mobile robot drive is possible thanks to the use of DC engines. Typically, gearboxes and encoders are coupled to motors, allowing, respectively, increasing torque and determining the positioning of the robot.

The learning of mobile robotic require the use of new techniques that apply concepts of “learning doing” and “learn to enjoy”, making student feel involved and motivated during the learning process. In this context, the LEGO Mindstorms platform appears as a flexible and educational tool to improve the learning issues of mobile robotics. A major reason that makes the Lego Mindstorms Kits interesting is to familiarize people with the construction of LEGO, where the pieces allow connectivity between them, eliminating the need to use screws or glue, making the construction of mechanical models much cleaner and easier. It is also a tool that contributes to sustainability, because the pieces can always be used in other projects. Besides the possibility of reuses, the kits are characterized by being a low cost alternative compared to conventional equipment on the teaching of control and automation. And is therefore a useful tool in the dissemination of there issues in a sustainable manner not only on the specific part of graduation courses but also in the basic disciplines of the course.

3. PLATFORM LEGO MINDSTORM

LEGO, a brand known worldwide, is a set of plastic parts for the construction of mechanical models. LEGO Mindstorms RIS (Robotic Invention System) is a platform that uses the basic concepts of LEGO to build mechanical models, used by millions of people around the world, allows learning by designing, inventing and experimenting computer-controlled systems such as mobile robotics. The flexibility and modular division associated with the LEGO Mindstorms platform allows to quickly create different configurations, providing a motivation for the public that its taking first steps into the world of robotics (and especially the world of mobile robotics) also is acquiring knowledge based on rapid prototyping technique (RESHKO et al., 2000).

The NXT, illustrated in Fig.1, is the programmable device, called logical block, he acts as the central control unit of a kit and where is placed the Mindstorms technology, that transforms mechanical models of robots and controls their actions. The NXT extends the possibilities of using the kit, allowing students to construct not only the structures and mechanisms, but also to develop knowledge and skills based on behavior control system.

FIGURE 1. .Block Logic NXT of LEGO.

The NXT has four entries (numbered with numbers 1 to 4) and three outputs (indicated with letters A through C). This means that the NXT blocks may collect information from the environment, using four sensors, and can add three devices performance. The common sensors used by this platform are the infrared sensors, touch sensors and sound sensors, as illustrated in Fig. 2. However, it is possible to obtain additional sensors to connect the NXT controller, such as temperature sensors, exploiting the potential of LEGO Mindstorm.

FIGURE 2 . Sensors provided by LEGO platform.

The platform provides two 9 volts DC engines equipped with a gearbox. The gearbox reduces the angular velocity of the wheel and increases the torque available. This work is based on the building of a forklift robot, illustrated on the figure 3, which used the tools aforementioned.

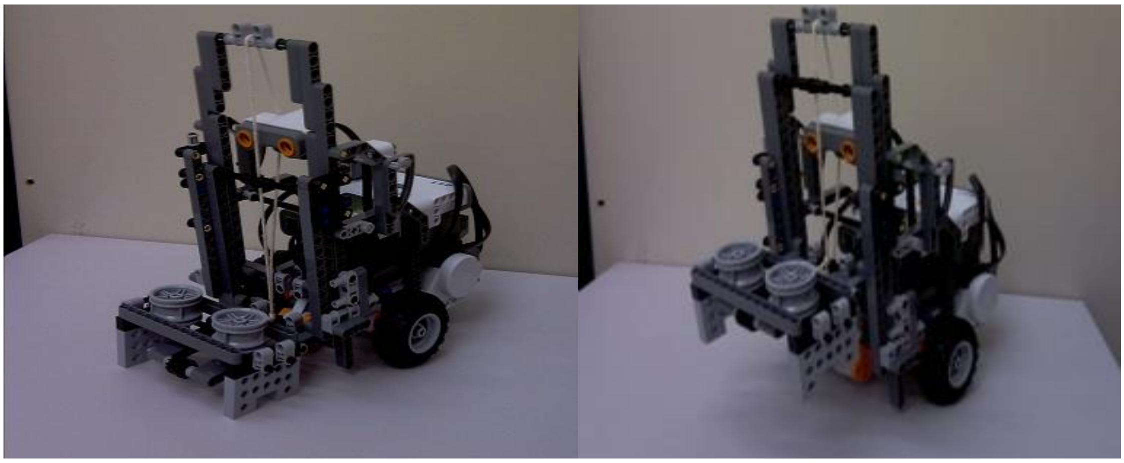


FIGURE 3. Forklift robot using LEGO.

Using the infrared communication, two NXT blocks would communicate with each other, expanding the input and outputs ports.

Being a widely used tool in the world, a set of important information's available to experiment and develop applications using the LEGO Mindstorms robotic, beyond that, there is also material available that is used to support educators and researchers who would like to apply Mindstorms on educational purposes (Mindstorms Comunidade, 2011). Other references which deal more investigative is also available (Bagnall,2002; Laverde *et al*., 2002; Ferrari *et al*., 2002).

4. ASSEMBLY OF THE ROBOTS PROGRAM

Programming the NXT can be performed within the RIS programming environment, which is a graphical programming tool provided by LEGO.

The graphical programming language RIS that consisting of functional blocks that are organized for the construction of programming. The control program consists of a se of large blocks which act as macros, ie, contains several sub-blocks, each performing a specific control task. For example, there are already pre-defined blocks to move the robot forward for some time and to turn left or right.

It has also included the so-called small blocks so that they act as functions that can be use to control some functions of macro blocks, such as to control the engine power, sound and communications via Bluetooth. The graphic language RIS also allows to build new macro blocks which could be re-used, or would be grouped a set of actions that will be used more than once on the robot programs. The programming language RIS also contains some helper functions, such as dedicated blocks to interact with the different sensors available.

The RIS programming environment allows the rapid development of programs for robots. Despite its advantages, mainly the simplicity and power intuition, the software NXT (NXT SOFTWARE, 2011), which can de seen in Fig. 4, presents some drawbacks, which creates some barriers to the development of complex tasks.

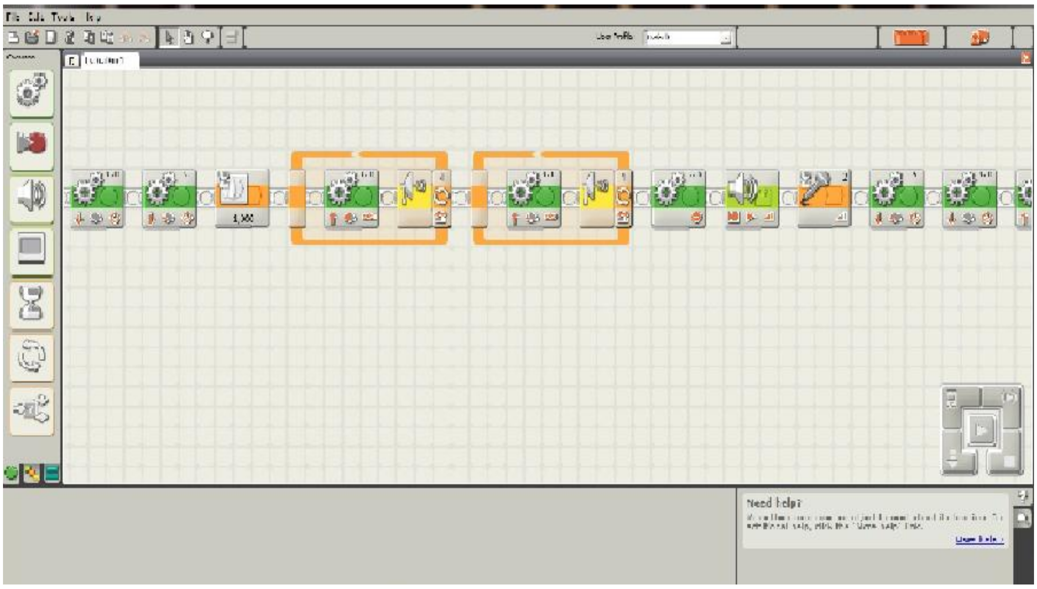


FIGURE 4. (Programming on NXT SOFTWARE v1.1)

5. PETRI NET (PN)

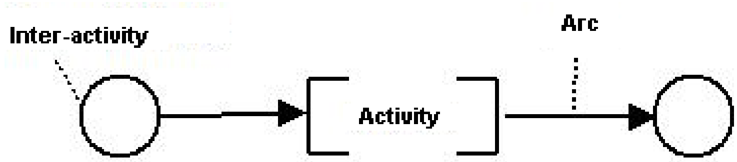
If compared with other techniques for describing discrete event systems (DES), such as Markov chains, queuing theory, process algebra, max-plus algebra, temporal logic, language theory and / or automata, the PN has an equivalent power of modeling; in addition, it has the feature and advantage of the ease of visualization system (Reisig, 1985, Cassandra, 1993, David & Alla 1994).

Some authors define the Petri net (PN) model homogeneous that includes a single formalism to describe the entire system. Other authors use the different formalism for each part of the system. The first is formally more elegant, but it presents difficulties to adopt a single point of view to all parts and the second is derived from the heterogeneity of real systems. As this paper considers a practical system, including abnormal situations the second approach is adopted, but to avoid the need for specialists to a large number o formalisms, only two PNs are considered.

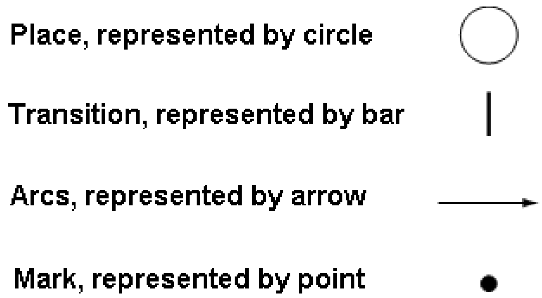
To model the dynamic behavior was adopted for a class of PNs place / transition, termed in this paper extended Petri net (e-PN), which were added timed transitions (terms related to PN are presented in Arial), inhibitor arcs and enablers arcs (David & Alla 1994). To construct these models a kind of PNs interpreted channel / agency called PFS (Production Flow Schema) (Hasegawa et al., 1999) is used. The PFS is a technique developed to systematize and facilitate the modeling of PSs. Starting system modeling at a high level of abstraction, and subsequent refinements are applied at each level the model is more detailed. The goals are to represent well the structure of the parties involved in implementing the activities and the flow on operations of productive process. In the procedure, from the refinement in PFS, the dynamic models of the system are generated using e-PN.

A PN is formally defined as a directed bipartite graph and an initial state called the initial marking (m0), being made up as follows (terms related to PNs are in Arial) arcs are oriented to both, places to transitions and transitions to places. A variable m refers to a place p a positive integer representing the number of marks should be drawn inside the place. In the model adopted at PN, a place represents a condition and a transition represents an event. Thus, for an event happens, all the preconditions of the event have to be met. When an event occurs, its pre-conditions fail to be satisfied, and their post-conditions (previously unmet) are now satisfied. In Figure 5a, has been an example of PNs.

The PFS is an interpretation of the PN to represent a conceptual level of abstraction of the system without consideration of its dynamics. The premise is that postponing the inclusion of dynamic rules of engagement there is a postponement in the model, avoiding an undesirable restriction on the details of a model, and the consequences of the invalidity of some of the hypotheses, which can lead to a costly restructuring of the model. Thus, PFS represents the essential elements of the system without detailing them, what can be done later, in a systematic and rational way. That is, when there is a more precise knowledge of the dynamics of the flow under study. The structural elements of a PFS that are represented in Figure 5b are: activity (active component) - represents an action or set of actions that change the status of the item, interactivity or distributor (liability component) that represents the availability of the items that flow into the system for displaying the states of this, and arc (material flow, people, information) represents the relationship between interactivity and an activity and vice versa.



(a) PFS.elements



(b) PN elements.

FIGURE 5. Petri Nets elements and it's PFS extension Elementos de rede de Petri e sua extensão PFS.

6. APLICATION OF LEGO MINDSTORMS METHODOLOGY

Proposed the use of collaborative design tools based on skills, relying on a functional-deductive approach, it starts with the definition of the general competence of the professional qualifications of the team involved, following two levels of competence: a) units b) elements, establishing themselves, still, for each element, the respective performance standards.

This methodological proposal, which will support the development of collaborative projects proposed, is shown in Fig. 6. The steps involved aim to add the technical and scientific knowledge beyond the basic aspects of behavior that will support the development of more complex skills.

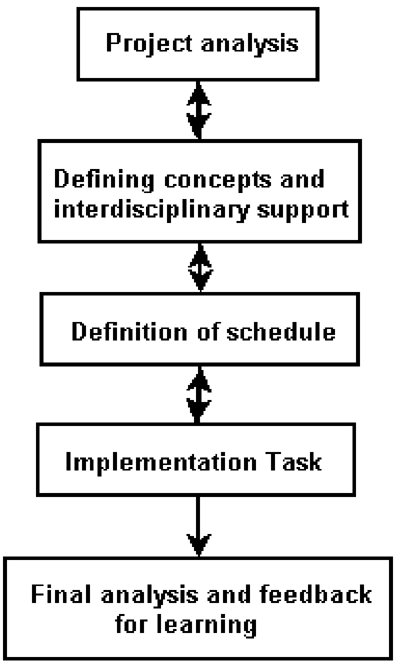


FIGURE 6. Driving the Project methodology. Condução Metodologia do projeto.

Following the concepts of pedagogic robotic, the LEGO Mindstorms kit was used in the development of a forklift robot, seeking the involvement of students on the construction and programming, applying the concepts off "learning by doing" and "enjoying learning".

After the assembly of the forklift robot was necessary to set the route for easy programming, which was used NXT SOFTWARE (NXT,2011), defined these steps were necessary to calculate the motions of the robot so that the objective was reached. There were calculations of how many rotations would be needed for the robot to perform a rotation of 90º and the times to achieve the goals.

After assembling the robot, setting the course and the calculations, the layout of controls was developed as a Petri net and PFS, represented in Fig. 7.

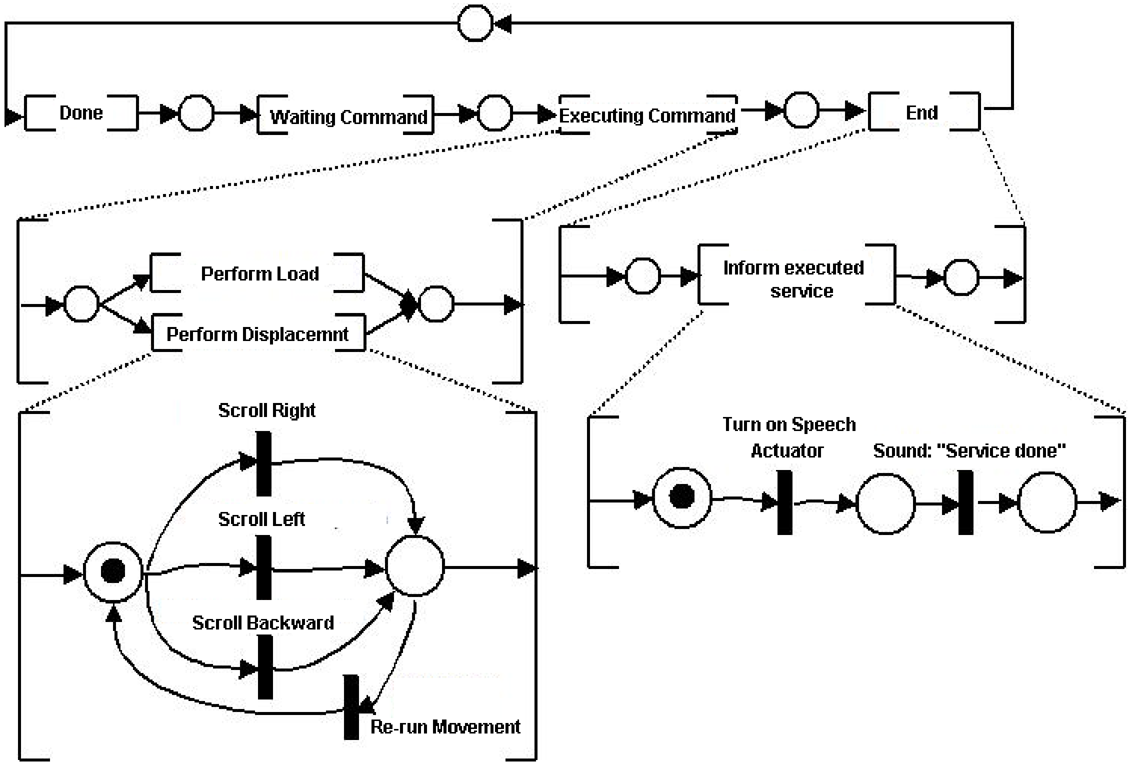


Figure 7. PN modeling of the control system of the robot forklift.

7. CONCLUSIONS

This article describes an experience using a LEGO Mindstorm platform to support the learning of mobile robotic theme. Due to the possibilities of rapidly build robots with different configurations, modules division and connectivity aloud for this platform. The idea is to put in practice the concepts of "learn doing" and "learn practicing".

The use of the platform awakened the interest of the students not only about the montage of the robot, but also on question related with operations. Noting that the student granted a bigger comprehension as physics aspects related with assembly as logics aspects of programming.

This project is part of wider one developed on PET-CA(school tutorial program – automation and control) ambit of UESC (Universidade Estadual de Santa Sruz) placed in Ilhéus BA. The PET-CA was made to contribute to the graduation of the students evolved. After all, on the most of engineering on control and automation graduation course is unusual students that do have contact with practical experience on control and automation area. The advanced topics learning on this area requires the applications of new methods of schooling, aim to motivate and evolve students on the learning process. Accordingly, the project involves the developing of tutorials and didactic models for who is involved. Looking for something that is easy to understand, flexible, attractive and instructional to overcome the challenges in several states of knowledge.

The meta-disciplinary skills, as team and competencies presentation, criticize thought, time management and competences of project management is also developed. These integrate methods of learning play a decisive role to the innovation and sustainability capacity of a company, because it corresponds to the demands of work's environment that the students will find during their future career. In this sense there is also a contribution on the development of sustainability because it intends to train students to innovate to use available resources appropriately.

Beyond the scientific development of the student to consider the current requirements of the disciplines involves, that is , the following developments, in result of this proposal, are considered:

(i) Implementation of prototypes for didactic cases.
(ii) Dissemination of modeling techniques, analysis and simulations of automation control, area encompassing and presence in cases of application.
(iii) Related work expectations, such as: the development of interface models for commercial simulators for discrete event systems, considering the mapping of a relatively large number off failures and events.
(iv) Development of the Petri net simulator that considers the facilities to describe and analyze the mechanism of control and reconfiguration of production systems.

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