A Simple Industrial Process Simulation with Mindstorms NXT as Tool in Automation Lessons

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Abstract

This work presents the development of a simulation prototype for an automated manufacturing process using the Mindstorms NXT LEGO© robotic kit. This process consists of assembling a basic product, namely a mini car done with LEGO© pieces, into two phases. First, the coupling of the body and chassis and after this, the separation of assembled products by colour. The intent here is to show that it is possible to create an automated system with NXT, like a mockup, that can be simulate a real system, and which has similarity to an automated system using a Programmable Logic Controller (PLC), with the advantage of being more practical and cheaper than an educational simulation system with PLC. The aims here is present an adaptable tool, to auxiliar the automation teaching and to motivate to use of new technological tools in classroom.

1. Introduction

Nowadays the automation is a development fundamental part of technology and several researches has been done searching for improvements. Created to industrial sector, where their origins were based on development of Programmable Logic Controller (PLC), and proved so efficient that began to be expanded for use in other areas. Your implementation too is realized in several ambient not industrial, such as, home automation (domotics), transport large as airplanes and ships, among other applications. Its application in various other fields has brought satisfactory results, which ultimately motivating new studies and search for new technologies.

There are theories focusing automation techniques improvement, but its application is experienced by few people due to the industrial process simulation complexity and the necessity of a reasonable amount of space to enable whole installation, this without taking into account the cost of the equipment and accessories needed for both.

In addition to this process being slow and expensive, it does not allow a rapid change in the structure to enable the simulation of the industrial process on a new configuration. Thus, it was proposed in this paper, the simulation of an industrial process with the LEGO© Mindstorms NXT robotic kit.

The use of this kit enables the realization of a very detailed plan on a smaller scale, thus the space required for the simulation is considerably reduced. In addition to creating structures, the kit enables the same to be automated thus has units of logical processing of data (here named bricks), which operate in a similar manner to the PLC. Another advantage offered by the kit, is the fact of working with equipment that does not pose risks, the use of Personal Protective Equipment (PPE) further reducing the cost of its use is not necessary.

Thus, Mindstorms NXT is a good option to simulate an automated process, which approximates well the real industrial conditions, thereby facilitating the absorption of knowledge in academia, presenting didactic teaching as an auxiliary tool.

2. Automation

Automation can be understood by any system based on computers replace human labor and aiming fast and economical solutions to meet the complex challenges of industries and services, being a consequence of several evolutionary processes occurring over time, aiming to seek improvements for the performance and productivity of people and also provide welfare to the population [1].

The first mechanical machines, nowadays considered quite simple, had the purpose of facilitating the most basic activities, especially those requiring strength. In general, these served as supports that extended the human physical ability. Later, machines that took advantage of the power of nature to support work, such as windmills and water wheels were developed. These machines, however, lacked a continuous human intervention [2].

The first of machines' sketches converting energy began to emerge in the early seventeenth century. As an example, the first steam machines those were erratic due to frequent variations in pressure. Subsequently, appeared machinery that regularly worked and they brought a range of applications previously impossible. This became known as Industrial Revolution, and was a major milestone, because it provided the transition from craft production methods for production by machinery, increasing productivity and repeatability, with consequent improvement of product quality [3].

In the late nineteenth century until the beginning of First World War, came the first machines carrying information either analog (telephone, radio) or digitally, and between the two world wars, were built several complex machines (aircraft, large ships, radars, among others). Was only possible to create them thanks to the development of the first techniques for industrial automation that were developed by J. von Neumann (1945) and N. Wiener (1948). They conceptualized safety and control systems based on switching systems [4].

In the same period appeared the first computers. A computer is composed of a series of integrated circuits and related components, which enable the implementation of a variety of sequences of instructions or routines by the user, and the rise of microprocessors, have improved controllers systems exponentially because it was possible to make smart them, since it was possible processing various data simultaneously [5].

In 1968 was created the Programmable Logic Controller (PLC), responsible for a major shift in industrial automation since replaced immense panels full of relays, for panels with only the PLC. Besides occupying less space, the PLC has the advantage of being programmable, allows a change to be made in the form of production of the product, it is only necessary the reprogramming of the same, which was not possible with the use of only relays [6].

Automation is a process that can be considered irreversible because it allows systems that were previously operated by many people, can be operated with a minimum amount, the officials responsible for overseeing the processes and equipment maintenance being only necessary. In addition to reducing the number of people participating in the processes, the evolution of automation afforded the exponential increase in production. Currently are being installed more often, robotic arms, which are tools that can perform repetitive work (often, were developed for this) and having a better than human performance, but accept journeys to more than 20 hours daily.

3. Industrial Mockup

Currently, industrial processes in general, are constructed and programmed without having a plant simulation process or a means which prior experimentation. The creation of a plant simulation for this purpose, assists in the study of process behavior, and help detect possible flaws in it and programming it before its implementation, thus optimizing the installation time for a new plant. It is common to observe computer simulation processes, however, these simulations fail to consider physical constitutive features that end up influencing much in the real production process.

The project focuses on the construction of a plant that simulates an industrial process through the montage with pieces of Mindstorms kit LEGO©. The plant was designed to simulate the process of assembling a product. This process was chosen because of the need for sensors that are used in virtually all industrial automated processes. The sensors are the touch sensor and the light sensor to work respectively with functions limit switch and proximity sensor in addition to the colour sensor used in the subprocess separation of the products by colour. The sensors are responsible for providing information to assist in decision making to drive or shutdown of actuators.

The chosen product to be assembled is a small car (Fig. 1c) done in LEGO© pieces with simplistic features due to the amount of parts available, they were not sufficient to treat prototypes of more complex products. It has been determined that the process to be simulated would be the junction of the base of the car (Fig. 1b) to the cabin (Fig. 1a) thereof, and then are divided into two groups and are differentiated by the colour of the body car.

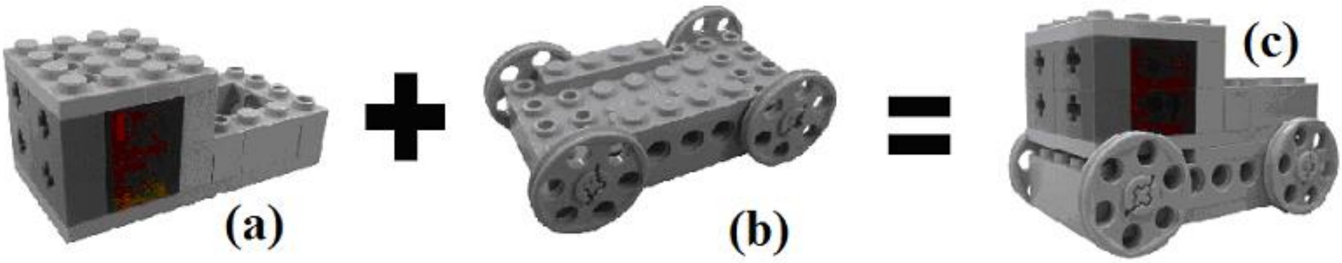

Figure 1. (a) body; (b) chassis; (c) assembled car.

In order to construct the mockup was planned a modular structure. The modularity serves to make the assembly more practical because it provides greater ease for mounting and for the transport and possible repairs. Modular systems are systems composed of subsystems (or modules) that join at strategic points within easy reach, and does not influence the behavior of the structure. These subsystems can work independently or have this feature, just for ease of assembly and transport.

In the mockup each module can operate autonomously and independent of the complete system, which provides mounting and schedule them separately. With this modularization of plant it is possible to make the modules can be built and programmed independent of the other, the unity of all being required only to simulate the entire process. To increase the organization of the plant, the modules were divided into four categories: transporter, platforms, assembly and colour sorter.

The transporters consist of conveyor belts that are responsible for transporting pre-assembled car parts (chassis and body) for platforms. The chassis transporter is triggered early in the process and the body transporter is triggered after the chassis comes in assembler. At the end of each track lies a light sensor, which is responsible for detecting the presence of the piece. After the sensor detects a piece, the conveyor belt turns until the piece can move over the platform and then turns off the platform, waiting for the process to finish.

The platforms are responsible for the correct positioning of the chassis and the body inside the assembler allows the assembly goes smoothly from poor positioning of parts. They consist of linear actuators that are controlled by timers, both moving forward as backward. Touch sensors that detect the stroke ending, acting as limiter, control the return. There is a platform for each carrier and both are triggered after the parts roam their respective belts.

The assembler module is starts after the correct positioning of the chassis and the body. The advance of a linear actuator performs the assembly process, which press the cabin over the base. After being mounted, the car is taken out of the mounting area, thereby enabling the start of a new cycle. Linear actuators, due to their strength, make both the assembly as the removal of the car. Touch sensors control the advance and retreat of the actuators and light sensors detecting when the actuators have been moved the correct course.

The colour sorter has the role of separating the cars in two colours, which are chosen according to the need or desirability generically denoted by "A" and "B". Classification of cars occurs even after the removal of the assembly process. After being removed, a light sensor detects the arrival of the car in the separation process, enabling the colour sensor to detect the colour of the car arrived. When the sensor is triggered, the information is sent to the controller that determines the colour of the car and compare it with the colours A and B, and from them to decide which place the car should be directed. After the colour has been detected mat rotates until a sensor detects that the car reached the end of the conveyor belt.

In addition, this module also shows if the car has reached, the module does not fit into any of the standard colours (A or B). When it detects that the car is not within the standards of colour, is thrown a pulsing light and sound, stating that there is an error in the vehicle. After this problem is detected, the module just hung light and siren after the car be removed manually. This is a method to ensure that the cars that are not within the standard, will have a special attention to finding ways to avoid repeating this mistake.

The system was divided into four subsystems or modules, which are grouped according to the following process. The subsystems created can be observed at Fig. 2, such: transporter and chassis positioning, named "Subsystem 1" (union of modules transporter and chassis platform), transporter and correct positioning of body named "Subsystem 2" (union of modules transporter and body platform), assembly and colour sorter.

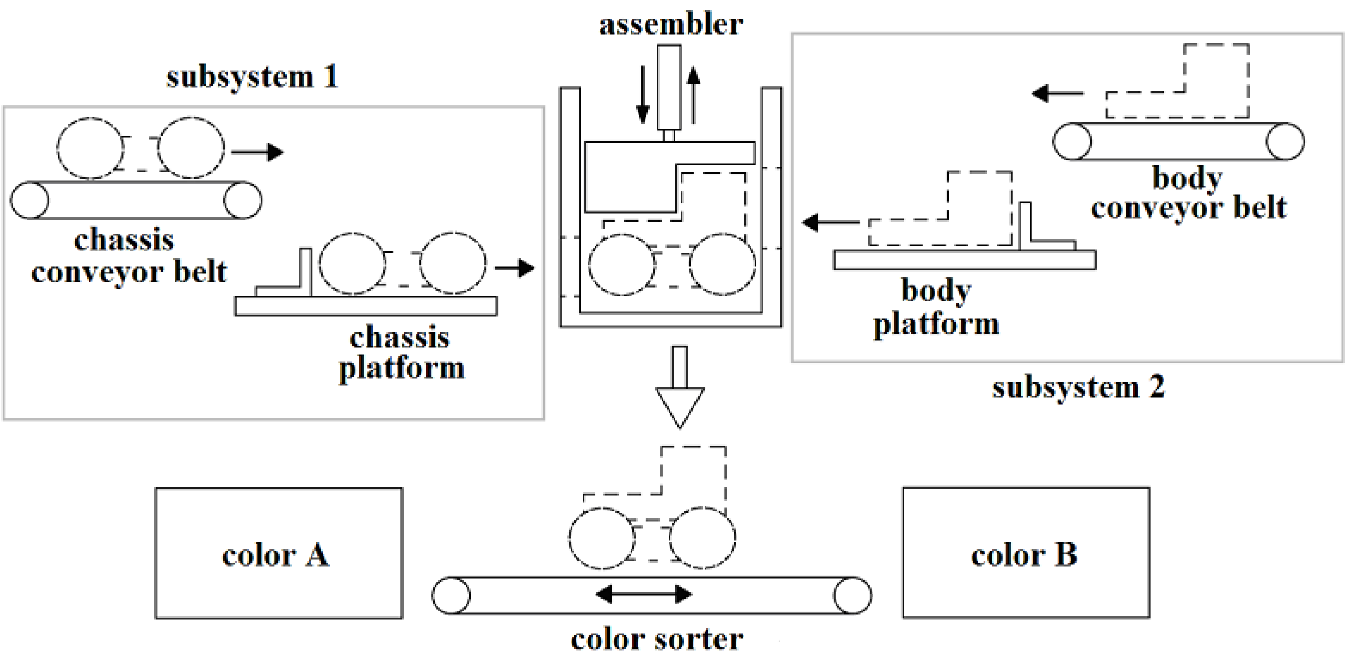

Figure 2. Schematic diagram of mockup.

Each one of modules can be seen at figures 3 to 8. The industrial mockup in their final configuration is presented in Fig. 9 displaying all modules. Its structure has a relatively large size for conventional assemblies in LEGO©. Being a modular structure, even with a relatively large size, transport, storage and repairs become simple, as are small structures, which are easy to handle separately.

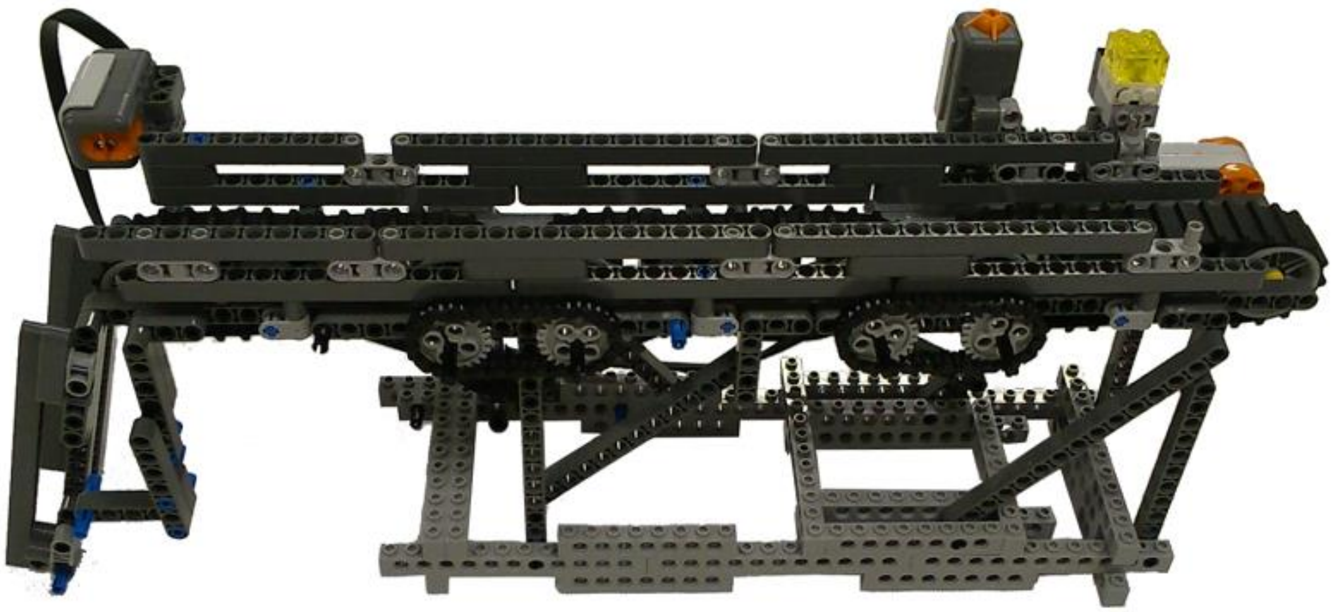

Figure 3. Chassis conveyor belt.

Figure 4. Chassis platform.

Figure 5. Assembler.

Figure 6. Body platform.

Figure 7. Body conveyor belt.

Figure 8. Colour sorter.

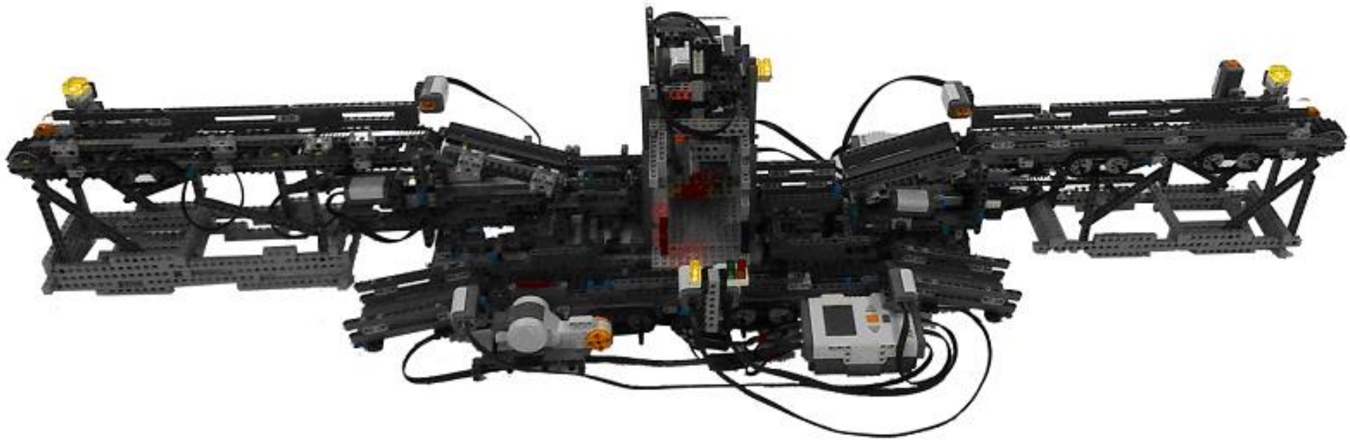

Figure 9. Full mockup.

The native language of Mindstorms (NXT-G) was used as programming software to the final plant, enough to control the whole process. Such programming language is based on blocks, making it therefore easy to understand. The program was constructed to execute the following actions:

Subsystem 1: the linear actuator should move back to the starting position (detected by a touch sensor), for proper operation of the plant during a cycle. After verifying its correct position, a light is lit indicating that the cycle can be started in that subsystem. Once the light is on, the following sequence will be executed every time the touch sensor is triggered, and can only resume after the start:

- keep the conveyor belt running until that the light sensor detects a chassis;
- move it until the body be completely out of the belt;
- move the linear actuator to the base to be positioned within the assembler;
- wait for the assembler remove the car out within its structure;
- return linear actuator to origin; wait the activation of the touch sensor to start the cycle (Fig. 10).

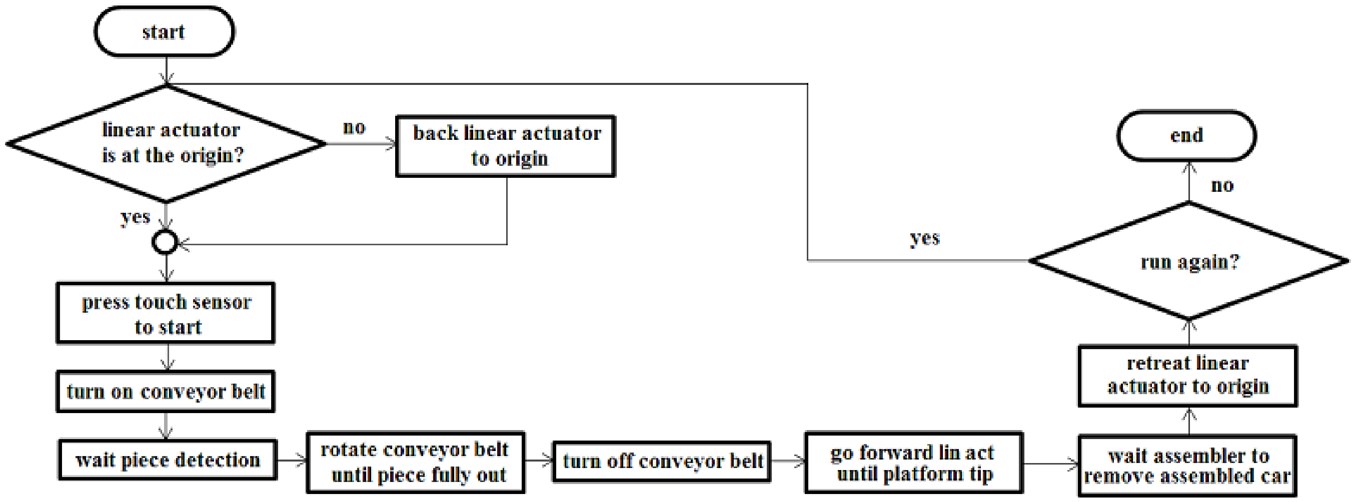

Figure 10. Fluxogram of subsystem 1.

Subsystem 2: similar to Subsystem 1, differing only by the drive cycle happens after the base is positioned within the assembler (detected by the touch sensor).

Assembler: To activate the programming (Fig. 11), linear actuators involved in the assembly and removal of the car-mounted, must go back to the starting position. After correct positioning of linear actuators is lit a light at the top of the assembler, which indicates that the process can be started. Once the light is on, the following sequence will be executed every time the signal is received that the cabin is positioned correctly and may only resume after the same:

- move linear actuator responsible for the assembly to the end position;
- wait one sec, to force the fit of parts;
- retract the actuator to the initial position;
- move the linear actuator responsible for removing the car from the structure until the final position;
- return the actuator to the initial position;
- start the cycle.

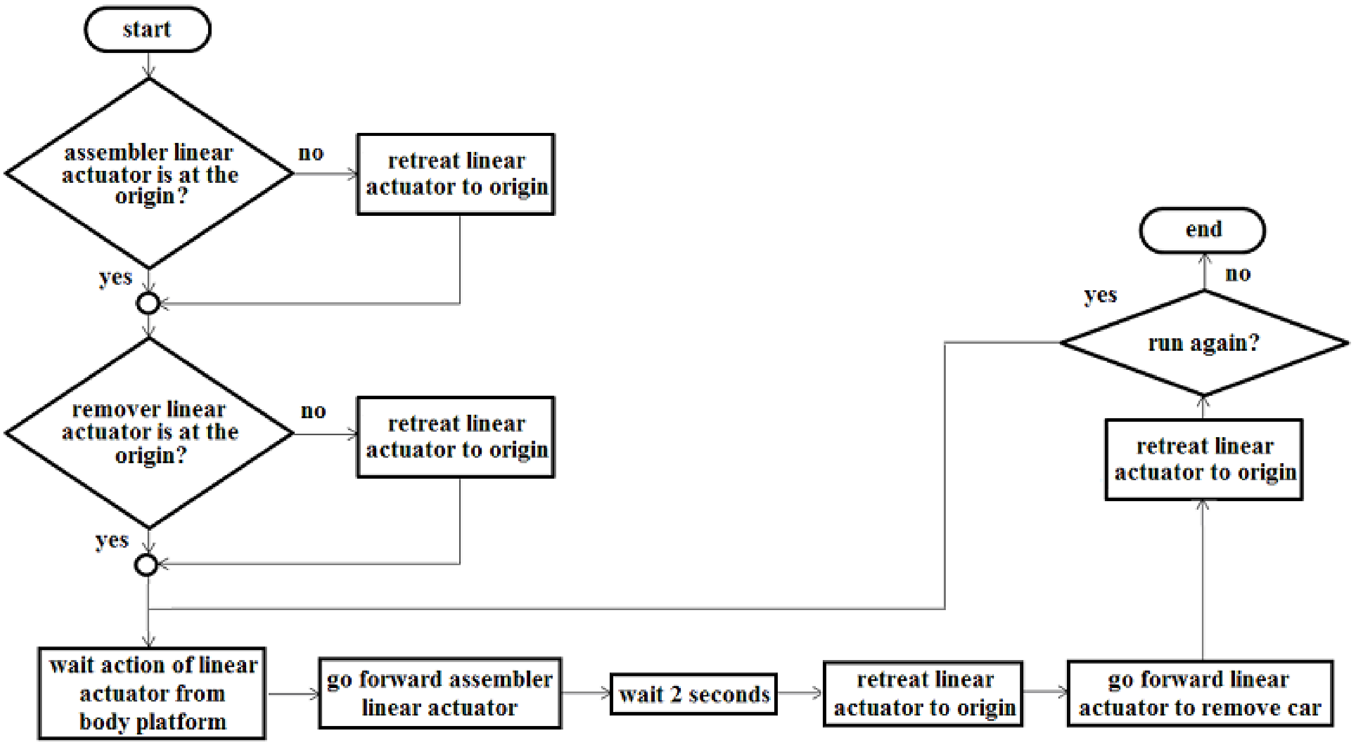

Figure 11. Fluxogram of assembler.

Colour Sorter: Upon detection of a vehicle in the exit area of the fitter, the colour of the car is analyzed, and according to this, the belt rotates in a defined direction until the car get out of it; not detect any case of colour, a warning light flashes, indicating that the car is not in any of the patterns. After the car leaves the track you hear a sound warning that the process ended. When there is no car in this module, a yellow light is on.

4. Conclusions

Simulation of a simplified manufacturing process was performed, using the actuators and sensors through a model of small-scale industrial plant. In addition to the physical part of the plant, is possible the application of more sophisticated techniques for automation, since NXT kits have few similar characteristics to the PLC. Besides this, exists the Bluetooth communication, enabling the creation of a network of communication between the bricks, thereby increasing the ability of plant automation. This type of model serves as a pedagogical support for teaching educational approaches, providing a new tool to the conventional teaching of automation and control. Some points can be raised as troubles in the construction of the plant, such as the quantity of pieces, which is a factor that can influence the full structure, that can became too much heavy. Beyond that, some errors may occur in the positioning of the chassis or the body, so that the assembly does not take place completely. This happens because the assembler have an aperture that provides observe the assembly process. However, this bug occurs in a small percentage. The mockup can be expanded and improved, showing more cases found in a real plant, showing different types of structures that can be created and also, the application of other sensors in the kit or even better use of the sensors used.

5. Acknowledgment

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