A ROBOTIC PLATFORM BASED IN FPGA FOR EDUCATIONAL APPLICATIONS

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ABSTRACT

This paper describes the development of a platform of control for support the learning of robotics, based in reconfigurable logic (FPGA – Field Programmable Gate Array). The platform receives external information from sensors. That information is processed by the FPGA that, at his turn, acts on DC motors. The communication between sensors, actuators and the FPGA is carried out by USB (Universal Serial Bus). The platform was developed for give support to the educational robotics using an educational system with suitable capacity of processing allowing a large range of the laboratory experiments, many kind of workshops of robotics, and advanced mobile robotics contest.

1. INTRODUCTION

The fast development of the integrated circuits conception resources, so much in the area of trials how much in the area of CAD, became possible the appearance of devices with reconfigurable logic. Such devices permit to the user implement complex circuits without the need of the use of burdensome resources of foundry in silicon [12].

The FPGA (Field Programmable Gate Array) supplies that flexibility to his users. This approach presents some advantages as:

- Circuits implementation capacity of big complexity;
- Flexibility in the reprogrammation, expansion and modernization of the original project;
- Reduction of the time of the cycle of development of a system of automation or embed system.

This comes from meeting to the fast evolution of the technological innovations of hardware and software in the area of embedded systems, automation and robotics. In these areas, becomes itself necessary develop application based in methodologies that take into account the facility of future modifications, modernizations and expansions of the system originally projected. However, for application in environments of study, basic, high school, under graduation or of post-graduation, conventional systems are not shown adequate. The main obstacle is the cost elevated of the most sophisticated systems limiting his use to a small streak of students.

This work describes a platform of control based in reconfigurable logic, applied to the study of mobile robotics, with a system of good performance, easy and adequate cost adaptability, supplying the possibility of the laboratory experiments achievement, offices of robotics and to even small competitions with affordable costs.

2. DESCRIPTION OF THE PLATFORM

2.1. Modules developed

The project is composed by three different modules: hardware, software and structural pieces. From those modules, is possible to build a large range of robot models for different kinds of challenge, enabling the application of the platform in own contest of mobile robotics.

With that, is possible dispose to the public schools a platform of robotics with medium, open architecture bass cost, flexible and easy handle, for support activities of incentive to the study of the science and technology building a community of users in form of net aiming at create an exchange of ideas and foment the study in the environment of the schools attended.

In the project proposed, the modules are described as is followed:

- Module of hardware: utilizing the technology of reconfigurable logic of the FPGAs, this module is responsible by the control of the actions of the robot through the job of the routines received of the module of software through an interface of communication;
- Module of software: responsible by the simulation of the actions of movement of the movable robot named Environment of Programming, by the communication between the hardware (RCX) and the Environment of Programming, and by the verification of the physical components of the robot;
- Module of structural pieces: responsible by the pieces that compose the physical structure of the robot, as: wheels, axles, flat bars, connectors, bases, etc.

2.1. Reconfigurable logic by hardware

Reconfigurable systems present the characteristic of replace part of his software or hardware for will adapt itself the specific task. Compared to the systems of reconfigurable software the systems of reconfigurable hardware present a bigger potential in we will have of adaptability and performance [13]. This proposal can be applied to systems subjects to the large technological variations in short space of time, be for the demand by new task and performances, be for the availability of new technologies of sensors and actuators.

An additional motivation for the use of reconfigurable logic is to growing availability of devices of big capacity and performance. Such devices dispose more of five millions of logical cells, permitting, including, the implementation of complete processors with program performed in internal memory [4].

The capacity of addition of new functionalities to an already existing system and the demand by tools of education for the formation of human resources in the area of healthy, educational robotics problems that can have its solutions attended with the utilization of the proposed platform.

2.2. Architecture of the hardware

The Figure 2a describes the architecture utilized through a diagram of blocks. Like this, the different modules of software and hardware can be seen structured in independent blocks.

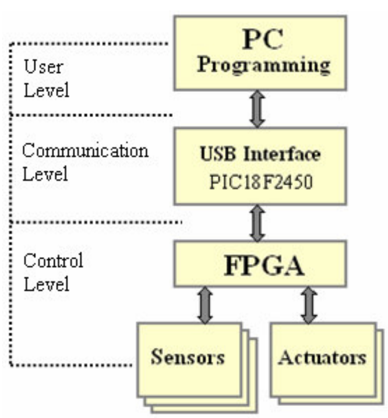

Figure 2a. The architecture implemented

Through the implementation of a hierarchical architecture is possible distribute the diverse actions of control utilizing resources of reconfigurable computation by hardware. With that, the different levels of processing and control permit a better distribution of the task graces to the possibility of processing in parallel, of form synchronic or asynchrony. The parallelism presents a big advantage in these kinds of projects since permits the construction of a lot complex models more near to the real models. Another prominent aspect is the possibility of implementation of new blocks in parallel to the already existing, permitting the improvement of the initial project.

In the proposed architecture, the hierarchical levels are described of the following form:

- Level user: utilized for supply parameters of operation and control level routines through the level of communication. In this level is possible the management and programming of the robot for the achievement of different task, according to the need of the user and the challenge to him presented.
- Level of communication: carries out the communication between the level user and the level of control. The transference of facts between these levels is carried out through an interface USB utilizing the microcontroller PIC18F2450 providing flexibility and adaptation to the requirements of project.
- Level of control: the task associated to this level is performed by routines implemented in reconfigurable logic. Through these, it is possible carry out the communication between sensors and control actuators, attending to the need of provide adequate processing of the information obtained of the external environment. Utilizing the FPGA, this processing can be carried out of parallel form, permitting that requisite of time of processing of the sensors and actuators are attended of more significant form.

2.3. FPGA Device

The FPGA utilized for the implementations in hardware was the Cyclone II EP2C5F256C8 of the Altera Company. This device is gotten on a standard development plate and the communication with the computer, with sensors and actuators is carried out through ends and connectors USB. During the development of the first prototype, were carried out many simulations utilizing the software Quartus II with objective of evaluate the efficiency of the answers obtaining projected control modules through graphics. With the achievement of those simulations is possible evaluate itself the processing time requirements are acceptable and itself the system is really answering as him expected, inside a margin of very small error.

2.4. Sensors

The ability of the robot of interact with the world and his behavior change is what does a robot be something so helpful and interesting. Without sensors, the robots would do nothing more than task you set of automation, or be, a repetitive work in a prudent environment acquaintance. For a robot, the sensors are equivalent to the organs of the hurt for the humans. All information that a robot has about the environment and around is provided by the sensors [7]. In the proposed platform, were utilized the following sensors:

- Optical Sensor by diffuse reflection;
- Sensor of passive touch.

2.5. Actuators

Actuators are devices that transform a determined kind of energy in another different kind. They are utilized in robotics for deliver to the plant the necessary excitement for their operation, in the form of adequate energy [5].

In this work were utilized two of those motors with the objective of providing to the robot the possibility of movement in everybody the hurt possible.

3. UNITS OF CONTROL

They are utilized two units of distinct control: the unit of control embarked and the unit of local control. In the unit of control embarked, a task is implemented: the decoder of commands. In this task there is decoding of the coming commands of the interface of communication USB embarked permitting the execution of different actions through the facts received. Then, the commands received already decoded Saints envoys for the unit of local control that carries out the reading of the sensors and generates the sign of control for the actuators. In the Figure 3a is presented the diagram of blocks of the unit of embedded control.

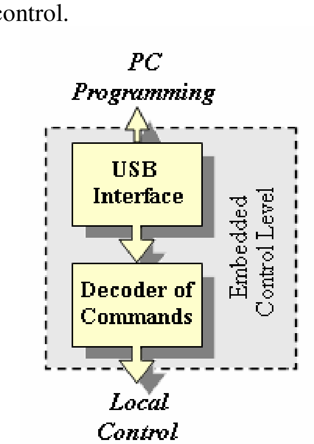

Figure 3a. Units of embedded control

The language VHDL (Very High Speed Hardware Description Language) was utilized for the development of the interface with sensors and of the control of speed and direction of the motors. The Figure 3b presents the diagram of blocks of the unit of local control, with the interfaces of sensors and actuators developed.

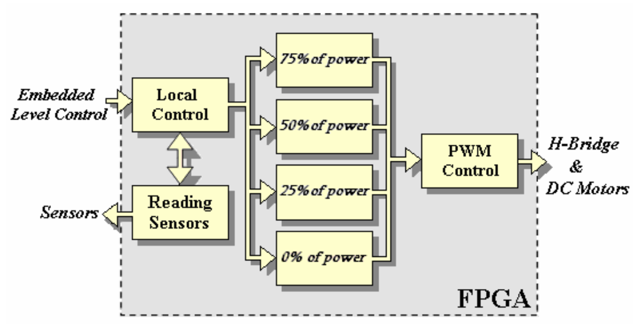

Figure 3b. Units of local control

With the interface developed for control of the motors, the user has the possibility of choose between three different speeds for his robot, as speed drops (25%), medium (50%) and high (75%), according to the need and the challenge to him presented. For that, the four levels of tension were put in distinct packages that are accessed by the healthy and local control envoys for the control PWM that, by his time, controls the direction of the axis of the motor and its speed. The packages are an assembly of logical doors and flip-flops that generate a sign of 8 bits that, subsequently, is sent for the controller PWM. How much bigger it will go the binary word in the entrance of the control PWM, bigger is the speed requested to the motors. By example, if the local control access the package of 50% of tension, then will be sent to the controller PWM the sign of 8 bits "10000000" that corresponds to the value "128", seen that the PWM has a span of "256", then, is carried out the comparison with the clock and the result is sent for the actuator. The Figure 3c presents the result obtained in the exit PWM after simulation utilizing the software Quartus II doing use of the facts cited previously.

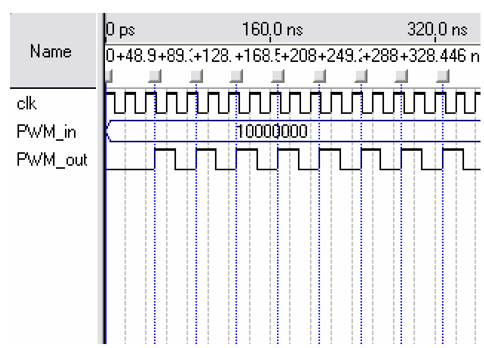

Figure 3c. Results on PWM output

It can be observed that applying the value of 8 bits "10000000" in the entrance of the control PWM, after certain delay, the exit presents a period from 50% of the time in high level. With that, a medium one of 50% of tension is sent to the actuator. The controller PWM consists of a counter, a comparator and some logical doors that operate of way it link or turn off the motor, control his speed or reverse the sense of rotation of the axis, be of the left or right motor. For control of direction of the axes, a H-bridge was developed. That bridge is controlled by the driver PWM through the utilization of 4 pines of the FPGA. In the unit of local control, also was developed the interface with the sensors, so that the processing execution time be attended of more satisfactory form than utilizing conventional computation. Like this, the time of reading of the sensors and processing of the well-read values is minimized and the local control acts with bigger quality in the motor. The Figure 3d presents an ongoing prototype of the robotic platform.

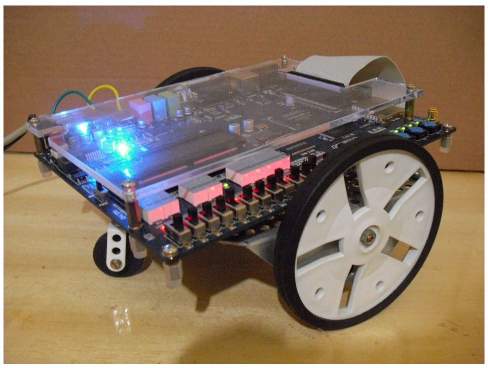

Figure 3d. An ongoing prototype of the robotic platform

4. CONCLUSION

In this paper was presented the utilization of FPGAs for control units development of high performance and easy adaptation applied the educational movable robotics. The implementation of hierarchical architectures was shown adequate, becoming possible the modernization of the final project and the construction of complex model more near to the real models graces to the possibility of processing in parallel. Beyond that, those models can be built utilizing simpler devices, reducing significantly the final cost of the project.

5. ACKNOWLEDGMENTS

This work was supported by the Financiadora de Estudos e Projetos – FINEP (Research Projects Financing), subordinated to the Ministry of Science and Technology (MCT), under grant Number 4971/2006-FINEP. Any opinions, findings, conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect those of the MCT and the FINEP.

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