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A CONTROL PLATFORM BASED ON DYNAMIC MODELING OF STRUCTURES

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ABSTRACT

In this work was developed a controller, using two experimental groups. The tests aimed at simulating a degree of freedom of a structure, allowing introduce inertial effects of changes over a trajectory and then assess the performance of a given technique under the control system disturbances.

It was possible to analyze the disturbance of the system and check the behavior of the driver in front of these disturbances. As well as the development of programs, can implement equations, and incorporate them into the mesh of control, using with the supervisory and control systems, making possible the systematic experimental procedures and thus assess the new structure of the control proposed. The results of this study provided the implementation of a control system based on the didactic dynamic modeling of structures, which can be used in other applications, such as the implementation of the controller in flexible and variable dynamic structures.

1- INTRODUCTION

The use of the devices which demand automatic control is increasing every day in an industrial generating an advances in productivity and delivering an uniform quality (Barak and Williams 2007; Ogata 2003).

Currently many of manufactured goods were replaced by manufactured products taking into account the use of machinery for the purpose of performing certain tasks with greater precision (Ohnishi et. al. 2007). For instance, the latest generation of robots used in industry can be considered fast and accurate, and the existing control algorithms are totally acceptable within the requirements (Chen et. al 2007).

The development of microprocessor increasingly versatile, speed and accuracy has enabled the use of advanced techniques for controlling the movement of manipulators. In many cases, it becomes necessary to use the structures of control with "open" architecture (Susano and Dumur 2006).

At the same time, the high cost of an adaptation of automatic machines used in traditional industries compared with the market and the need for research in the area require the development of research in order to adapt the existing handlers for automated operations which allows the execution of teaching duties in connection with education, extension and applied research to engineering (Oliveira 2003)

In this paper we have investigated, by means of the usage of two experimental groups, (nonlinear controller and classical PID controller) the implementation of a control system based on the didactic dynamic modeling of a structure. In order to realize this task we used the reprogrammable software components in ALTERA™, which favored the development of control algorithms using libraries themselves.

2- OBJECTIVES

This paper aims is proposing a development of a platform that represents a system of controlling position for a structure like a one-link manipulator.

Initially can be used a classic-controller PID (Proportional, Integral and derivative), which will be studied from the behavior of the system simulations in the presence of disturbances.

To implement the project should be a theoretical study to verify the following:
-the approaches used in the analysis and design of nonlinear control systems;
- the nonlinearity most often found in servo-systems;
- the use of non-linearity intentional as rewarding actions on the nonlinearity inherent in the servo-system;
- to obtain functions of the blocks transfer to nonlinear (also known as descriptive functions) from the response of the same input signal;
- to obtain a mathematical model to a servo-mechanism, from a physical model representative.

The theoretical justification of the results of the model will be carried out through numerical simulations, using a computer package.

With that will build a library of robotics, where several blocks will be implemented for non-linear modeling of a robot, the complete system of drive and nonlinear controller. This library will facilitate the implementation of the mesh of control of robotic systems in general.

3- MATERIALS AND METHODS

3.1- Methods

The working method used was an initial study of dynamic modeling of a structure (David, 2008) through numerical simulations analyzing the behavior of the system in the presence of disturbances, using a traditional PID controller and nonlinear control.

To achieve this purpose was developed a controller using two experimental groups. The tests aimed at simulating a degree of freedom of a structure allowing introduce inertial effects of changes over a trajectory and then assess the performance of a given technique under the control system disturbances. This stage of work has enabled the acquisition of accurate data and variations of the load.

Thus, the purpose is to analyze the disturbances of the system and check the behavior of the driver in front of these disturbances.

As well as the development of programs, it can implement equations, and incorporate them into the mesh of control, using with the supervisory and control systems, making possible the systematic experimental procedures and thus assess the new structure of the control proposed.

With this fact in mind, we have proposed a platform that will be describe in the next sub-section

3.2- The Platform

The platform (Figure 1) would be formed from an electric DC motor coupled to two disks of inertia and sensors of incremental position.

The first disc solidarity of inertia is coupled to the engine axis, while the coupling of the second disc of inertia is accomplished through an electromagnetic

clutch, which is used to connect or not a new load to the engine, thereby allowing varying the inertial load of the system (similar effect to a change in configuration of a robot in a specific trajectory).

Through this variation of the load we have a disturbance to the system, which will enable us to verify the behavior of the controller due the disturbance. The initial speed of the load induces a disturbance on the system.

After a while the clutch no more slides and speed of the second inertia is then equal to the motor. We can consider this torque as a disturbance of the change of parameters of the system.

To identify precisely the dynamic behavior of the link on the motor and load and the influence of coupling and gaps in the system will be used two incremental encoders, one in the axis of the load (after the reducer) and another on the axle of the motor.

The platform has the following characteristics:

- simple mechanical construction made with low-cost commercial components;

- presents the opportunity to simulate one of the degrees of freedom of a robot without dynamic coupling between the joints, allowing the realization of a number of experiments of great interest both from the scientific point of view as academic.

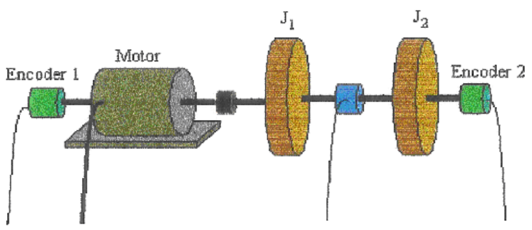


Figure 1: The platform proposed

Considering the non elasticity of the system, physically the coupling imposing the conservation of momentum of the entire system, with loss of kinetic energy, linked to the initial slip clutch.

Meanwhile, in the moment when the clutch is actuated, there is no change in the inertia of the motor, thereby producing no disturbances on the system and not change of speed or loss of energy.

The torque delivered by the clutch must be sufficiently high to avoid slipping during the engagement; anyway, this action introduces a non-linearity on the system. To avoid this slide is necessary to verify:

$$T_{clutch} > T_{motor} \frac{J_2}{J_{system}}$$

(1)

where:

T_{clutch} - Torque applied by the clutch

T_{motor} - Torque on the axle of the motor

J_2 - Inertia of the second load

J_{system} - Inertia of the system (motor + load 1)

In short, the proposed platform is very close to a degree of freedom of a robot, with a small difference: because of the second load enter into the system almost instantly. In the case of a robot, this variation is continuous on the time.

The clutch is powered by electric command and, once triggered; it engages the second load to the system. With this variation of the load we have a perturbation to the system, which allows us to verify the behavior of the controller.

Under these aspects, this platform is presented, in general, as an interesting structure for validation of different control algorithms.

3.3- Processing Information

For processing of information from sensors, together position and the implementation of nonlinear controller and classic PID controller and electronic programmable logic device (EPLD) were used in the ALTERA™ component. This component is enabling the development of control algorithms using their own libraries

and even the development of programs and include within the mesh of the control system.

The main advantage of this implementation was the fact of implement the mesh of independent control of the PC used as a system of supervision and control.

That gives us a complete freedom of application since we will not depend for example micro computer clock to execute the program.

3.4- Supervision and control system

For experimental validation of the proposed experiment was conducted initially the process of identifying the real parameters of the system, through the implementation of a system of acquisition and control.

This made possible the systematization of experimental procedures, allowing quantitatively assess the new control structure proposed. The Figure 2 below shows a schematic representation of the experimental infrastructure proposal.

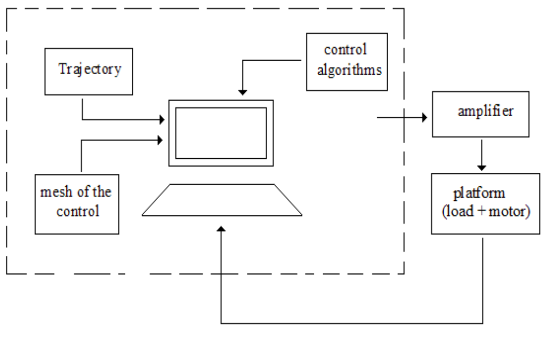


Figure2: Schematic representation of the experimental infrastructure proposal

The system consists of two micro computers, one responsible for acquisition of information from the transducers of position of the platform (after treatment in ALTERA™), and the other responsible for the generation of signals of reference (or track) to the controller. This allows an error analysis of the behavior of the trajectory of reference after compared with the final position of the load measured in relation to the axis of the motor and the load.

The generation of a path is achieved by a computer program to send files of points (coordinates of joints) for the controller of position of particular joints in dedicated hardware developed in reprogrammable logic using the ALTERA™.

During the development of this work were carried out further studies in order to obtain the parameters of the experimental platform used. We can refer them:

- Obtaining the parameters of motor (reduction of inertia, inductance);

- Obtaining the parameters of reducing and the inertial load (moment of inertia, friction) , and

- Calculation of gains for a PID controller

3.5- Controlling position

3.5.1- The development system ALTERA™

The components PLD (programmable logic device) have been showing in recent years as a valuable tool for validation of hardware designs.

Their speed, integration capacity, flexibility and ease of programming also present an attractive solution in the design of controllers.

One of the proposals of this article is to propose the implementation of a controlling position using PLD. One of the advantages of this implementation is the low cost and no need to use of converters AD - DA.

The main choices are:

- Possibility of implementing the project in graphic language (schematic), VHDL (hardware description language) and AHDL (ALTERA Hardware description language);

- Use of various types of packaging for the design of the interface in printed

circuit board: PLCC, PGA, PQFP, TQFP And RQFP;

- Variety of PLD families, allowing the choice of device that best adapts to the Project;

- Possibility of creating libraries dedicated and structured programming environments;

- The development system can be implemented in platform-type IBM-PC allowing the simulation, analysis of diagrams of time and programming directly from the device.

3.5.2- Proposal controller's position

This interface has the main objective, the control of a DC motor powered by a power driver linear or PWM.

The programmable controller is able to process the digital signals directly from a shaft encoder coupled to the engine and a digital signal control representing, for example, the trajectory of a joint robotics.

In the Figure 3 is shown a schematic representation of the structure of the control system implemented in this work.

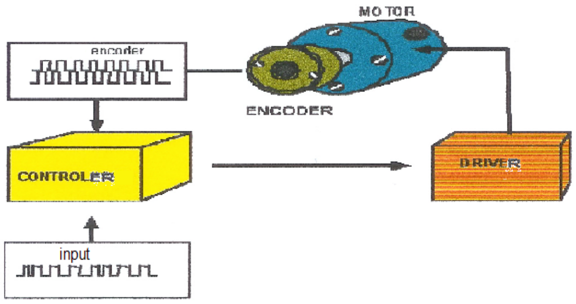


Figure3: Blocks diagram of the system

In the experimental implementation of this project were two procedures used for generating the output signal of the controller:

- Generating a 16-bit binary code that will be sent to a DA converter, which in turn generates a voltage control module for the power.

- Generating a digital signal to the module with power control by pulse width modulation (PWM). In this case, no converter is needed in the mesh of control.

3.5.3- Trajectory

Trajectory is a digital signal (train of pulses) for the input of command for the drive system. He has the following characteristics:

- This signal is related to its period the speed with the trajectory is executed;

- The number of periods (or pulse) is associated with the displacement executed in this path;
- It defines the practical limits for the signals generated for the trajectory (maximum and minimum values).

3.5.4- Encoder

Encoder is a digital signal (train of pulses) from a position transducer coupled to the axis of the motor (incremental encoder). He has the following characteristics:

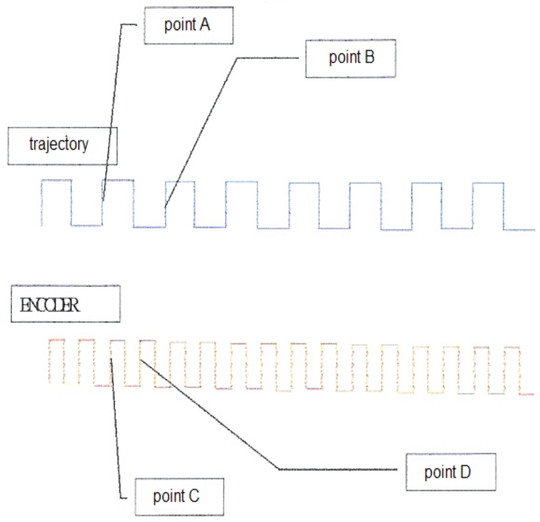
- This signal is related to its period the rotation of the motor. - The number of periods (or pulse) is associated with the angular displacement of the shaft of the motor;

- It defines the practical limits for the signals from the transducer (maximum and minimum values).

In order to exemplify the behavior of the system are shown in the Figure 4 typical examples of input signals in two situations:

a-)the motor that accelerated with the signal encoder featuring a sign that higher trajectory, and

b-)the motor is decelerating with the signal encoder featuring a period less than the signal path.



(b)

Figure 4: Typical examples

3.5.5- Environment simulation

The environment of simulation system modification allows the design of the input signals and consequent viewing of output signals simulated.

This simulation is quite sophisticated, allowing them to be considered for setup and hold time, delay and glitch. In the following Figure (Figure 5) is displayed a diagram of time taken from a display of graphic simulation, where the meter displays the results converge to zero as the periods of the signals compared are approximated.

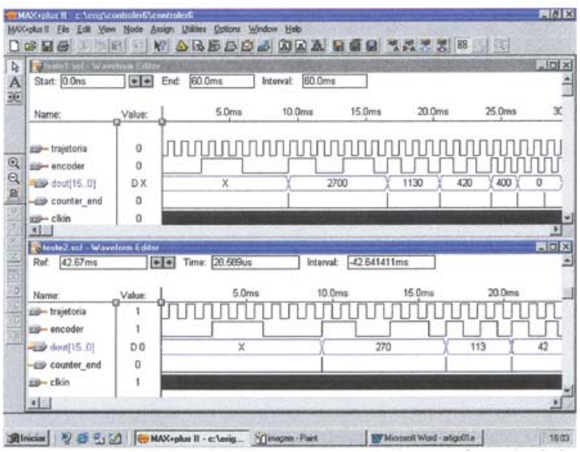


Figure 5: Graphic simulation (time diagram)

3.5.6- Experimental prototype

For the implementation of the controlling position described in this paper was developed an experimental prototype (Figure 6) of logic circuits reprogrammable ALTERA^{TM}.

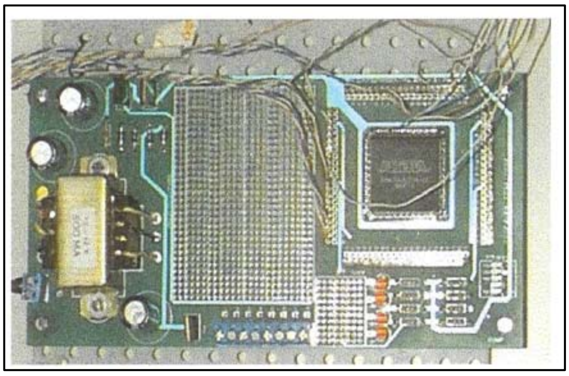


Figure 6: Experimental prototype

The use of these components allowed the high capacity of integration of resources and its open architecture and structured programming, from the implementation of two modules i.e. , *module for acquiring and processing information* and *module of controlling position* which will be describe in the next sub-section.

3.5.7- Acquiring and processing information

The module for acquiring signals and processing information of the position sensor from the processing of signals generated by the encoder was carried out by a logic circuit using logic reprogrammable, which allowed obtaining the direction of rotation and frequency.

From a circuit of counting such information were sent to an interface I/O to a PC, thus enabling a further processing of such information (quantitative analysis of results).

3.5.8- Module of controlling position

The position of the control module has been implemented in logic reprogrammable in a position to control proportional to allow the comparison of digital signals of reference from a PC, with the angular extent of the joint through an incremental encoder (module of information processing described previously) and on the basis of error of the joint, a signal in form of pulses was sent to the amplifier to the system powered of

motor. The next Figure (Figure 7) is shown in order to be easier the understanding.

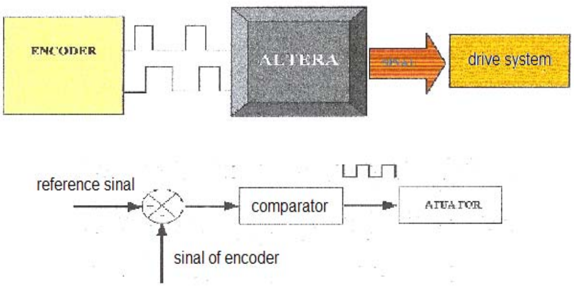


Figure 7: Control of proportional position

4- RESULTS AND PROSPECTS

To achieve the purpose of the paper was developed a controller using two experimental platform for testing in order to simulate a degree of freedom of a structure (like a one link manipulator), making it possible to introduce inertial effects of changes along a trajectory and thus evaluate the performance of a given control technique subjects the system disturbances. This stage of work allowed the acquisition of accurate data and load change. Thus it was possible to analyze the disturbance of the system and verify the behavior of the driver in front of these disorders.

In the processing of information from the position sensors of the joints and implementation of the nonlinear controller and classical PID controller were used reprogrammable logic devices (EPLD's) in the ALTERA™ environment, which favored the development of control algorithms using their own libraries. Well as the development of programs, it is possible to implement equations and include them within the control loop system. This helps to implement the control loop independent of the computer, using as a system of supervision and control, making possible the systematization of the experimental procedures and thus to quantitatively evaluate the new control structure proposal.

5- CONCLUSIONS

The study aimed to modeling and simulation of dynamic systems with emphasis on the study and implementation of controllers position. To this, was structured a system to control a robotic manipulator, implementing a new system to control the location of open architecture to perform additional automated tasks from the knowledge of the environment of operation and type of task to be performed, and thus investigate the use of different types of control structure.

The working method consisted of an initial study of dynamic modeling of a robot manipulator, from analyzing the numerical simulations the behavior of the system under disturbances, using a classical PID controller and nonlinear controllers.

Besides these contributions, we also include the development of a position controller for a robotic joint using a PLD, which highlight the advantage of its low implementation cost and no need to use DACs.

Finally, the results of this study provided the implementation of a control system based on the didactic dynamic modeling of a structure, which can be used in other applications, such as the implementation of the controller for structures of dynamic variable, robot manipulators and flexible structures.

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