DEVELOPMENT AND CONTROL OF A MECHANIC ARM FOR EDUCATIONAL PURPOSE

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Abstract. *In recent years, there has been considerable effort by educational institutions in improving technical courses / technology and the employed methods of teaching and learning. There are several reasons leading to such changes, among them we can highlight the need to awake new skills in students, as well as to provide interpersonal and interdisciplinary participation, seeking the development of new technologies and creativity. In this context, this work aimed to develop a robotic arm with an educational purpose. Controlled by a computer system, it can serve as a platform for studies and tests, through application of theoretical knowledge in related disciplines. The structure of the robotic arm was composed of base, joints, linkages and gripper. The base and the joints are servomotors responsible for their movements, clockwise and counter-clockwise, up and down. The grippers are meant to pick up, secure and transport the object from one point to another. The acrylics, links, have the function to interface between the joints. This study is aimed at a teacher's aid, technical and technological areas, in the development of interdisciplinary, since the various areas and steps required building the arm, involved practical and theoretical contents in mechatronics.*

Keywords*: Engineering Education, Teaching Assistant, Mechatronics Systems*

1. INTRODUCTION

Currently there is a growing need in our society for creative professionals, freelancers that are able to face new challenges. As a consequence, educational institutions are focused in the improvement, adaptation and creation of new different courses in order to develop other skills and abilities that lead to the application of technology in modern life.

The search for new tools that is effective in teaching and learning through the enhancement of motivation and a wider range of possible content, form part of some aspirations for professional education. Another important point is the interpersonal and interdisciplinary teamwork necessary and which lead to the development of new logic and creativity. With this purpose, we identified the opportunity to create a platform for research related to robotics, which due to the diversity of disciplines involved, allow greater scope in the application of the acquired knowledge.

This platform is a robotic manipulator arm, controlled by a computer system, where students can follow all the steps of planning, building and programming.

Thus, it is described in this paper the components necessary to build a robotic arm, the steps applied in the development of the proposed mechanic arm; the project is stating the difficulties and successes of this project accomplishment.

2. DEVELOPMENT OF MECHANIC ARM

Robotics today is unfolding in a very broad spectrum of applications: industrial, medical, aerospace, subsea, among others (Rosário, 2008). However, its dominant feature is still dealing with problems posed by structural and functional development of machine, such as:

a) Robot manipulators being able to grip objects and move them, or act on objects with specific tools.

b) Mobile robots moving on wheels, feet or tracks.

2.1. Structure

The mechanical arm is a manipulator designed to perform different tasks and be able to repeat them. To run them, the robot moves parts, objects, tools and follow the special movements and pre-programmed points.

In this design, the arm is constructed using acrylic, which can be considered engineering plastic; whose main characteristics are transparency, weather ability, luster lightness and stiffness. Thickness used is two (2) mm in the links and three (3) mm at the base.

The links are connected by joints that allow them a relative motion between them "fig.1". Thus, in any location of the link, there is a board that will join the next link, allowing it to move.

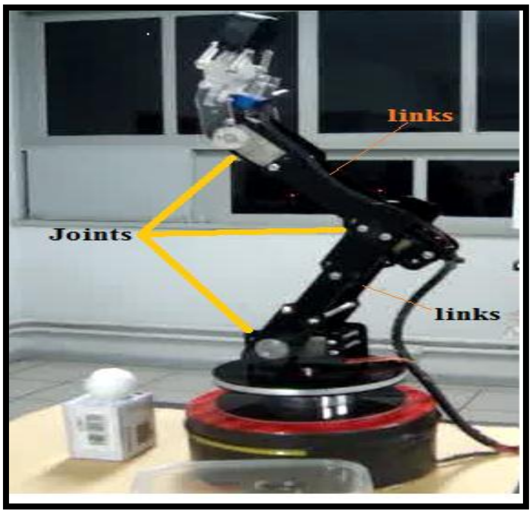


Figure 1: Union of links

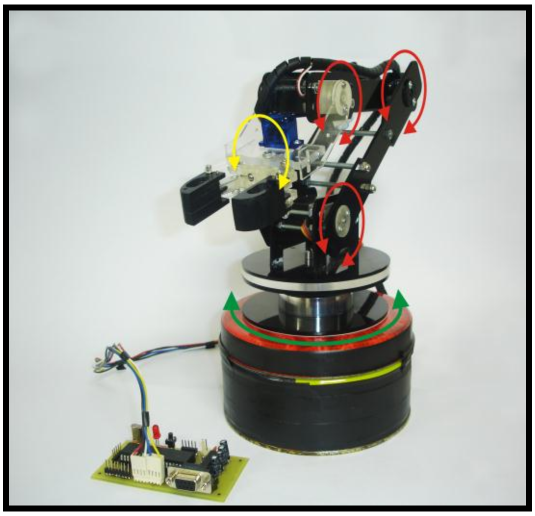


Figure 2: Generalized coordinates

All Joints determine the possible movements of the manipulator, and are driven by different mechanisms of mechanical power transmission such as gears, pulleys, chain and screw drive. It intended to give the movement the desired direction, strength and speed.

The endpoint of the last link is known as a handle, which is usually attached to a gripper. Since the first link is usually plugged into a base, usually attached to the floor in industrial environments. The base holds all the mechanical arm, and serves as a support and reference for all their movements.

The last three joints are intended to guide the actuator in an arbitrary direction appropriated for the task to be performed. These joints are always of revolution, because the goal is the orientation of the gripper and not its position. The generalized coordinates or variables that characterize the movement of these three joints are angles that are named pitch, yaw and roll.

The joint enables the roll rotating clockwise and counterclockwise, simulating the rotation around the wrist of the arm. In characterizing the yaw is the rotation of the actuator on the right or left, since the board is responsible for the pitch moving up and down.

In this project, we used the coordinates of robot revolution, with the pitch and yaw movements demonstrated in "fig.2".

The workload refers to the space within which the robot can manipulate the end of your fist, being determined by the characteristics of the robot as its physical configuration, the sizes of the components of the body, arm and wrist, and limits the movement of joints.

Generally, it is not considered the presence of the gripper to define this volume, because in this case, would depend on the size of the gripper being used in each task (Pazos, 2002).

2.2. Gripper

The gripper is the component of the robot designed to pick up and hold heavy or light objects for their displacement inside the workspace of the manipulator, depending on the type of application and position of the gripper.

For construction of the proposed arm, two gripper fingers were selected to be capable of performing a parallel movement to hold the object, and a rotation to facilitate the positioning of the brag "fig.3". For this last move, despite having been designed a structure for its implementation, it was not developed in this project.

The main disadvantage of this gripper (two fingers) is to limit the opening of the fingers, thereby restricting its operation on objects whose sizes do not exceed the maximum aperture.

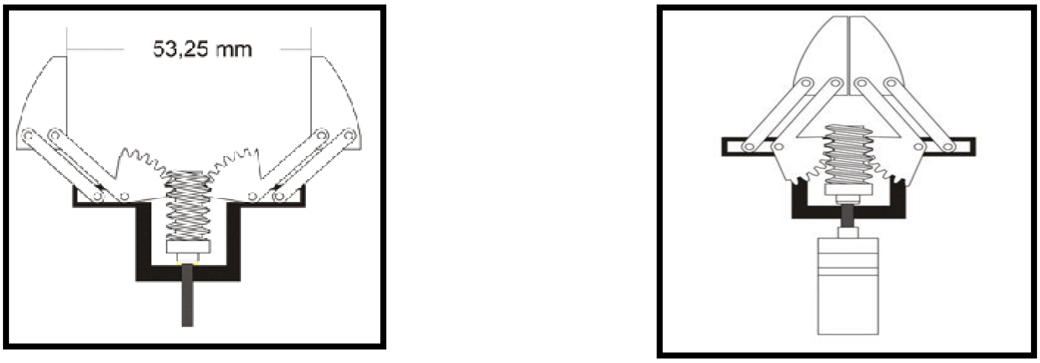


Figure 3: Gripper designed

2.3. Servomotor

The servomotor systems are electric motors with the additional property of controlling position, speed and strength or though voltage, current, or frequency, depending on their structures. Basically, they are motors that operate with precision positioning and high degree of repeatability (Francisco, 2004). For this reason, the engine servomotor was chosen to construct the manipulator arm.

The servomotors are used to control an angular motion, typically between 0^o and 180^o since it is mechanically able to run more because of a potentiometric and a mechanical stop on the output gear “fig. 4”.

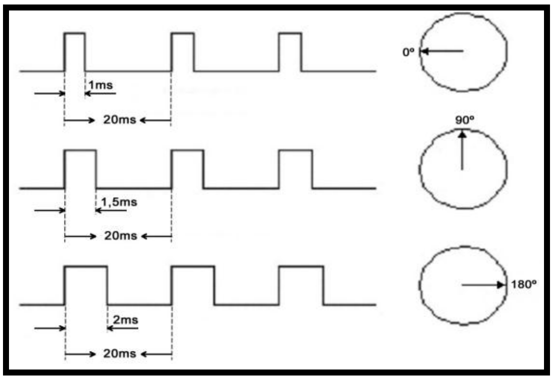


Figure. 4: Control of the rotation angle of the servants (Francisco, 2004)

The supply voltage for the servomotors is usually between 4.8V and 6V, but it is recommended 5V. The lower the voltage, the slower the response of the servomotor and the lower the torque. The supply current depends on the power of the servo (Table 1).

Table 1 Manufacturer's specifications for the servomotors or used acquired (Figures 5,6,7).

Type	SG90	SG5010	MG995
Dimensions (LxWxHmm)	23x12,2x29	40,2x20,2x43,2	40,7x19,7x42,9
Weight (g)	10	38	55
Speed (S/60°)	0,3	0,4	0,2
Torque (kg*cm)	0,5	2,5	5,0
Maximum Torque (kg*cm)	1,5 (5V)	4,5 (6V)	10,0 (6V)
Period (us)	10us	20us	10us
Temperature (℃)	0—55	0—55	0—55
Voltage (V)	4,2—6V	4,8—6V	4,8—7,2V

2.3.1 Control of the rotation angle of the servants

The angle of rotation of the servants is determined by the duration of the pulse that is applied in the command input. The servo operates in PWM (Pulse Width Modulation) system that consists of generating a square wave that varies in pulse duration, keeping the wave period.

The minimum and maximum width of the pulse depends on the type of servant. However, in the general case, if the servant receives at its input pulses with a duration of 1.5ms, its axis until it runs stable at the center of rotation interval, which corresponds to the angle of 90^0. If it receives pulses with duration of 1ms, wheel in a counter clockwise direction until it reaches the limit of the range of rotation corresponding to 0º. If pulse with duration is 2ms, wheel clockwise until you reach the other limit of rotation interval corresponding to 180^0, or a little more (Rosário, 2008).

2.4. Language

Currently, most commercially available microprocessors have C compilers for software development. The development in C enables a high speed in creating new projects, due to the ease of programming offered by the language and also to their portability, which allows programs to adapt one system to another with simplicity and efficiency. The C language is considered a high-level language allowing the programmer to worry more about the programming of the application itself, since the compiler assumes duties as the control and location of variables, math, logic and checking databases memory.

3.0. THE PROJECT

The aim of the project is to build a robotic arm with powered programmable and anthropomorphic features, and a brain in the form of a computer that controls its movements. The computer stores in its memory a program detailing the course to be followed by the arm, sending signals that activate the motors that move the arm and the load at the end of it, kept under the actuator control.

3.1. Components

The robotic arm with educational purpose has five degrees of freedom. For its assembly, it was purchased five servomotors; the gripper motor has the following technical characteristics: size 3x12, 2x29mm, weight 10g, with maximum torque of 1.6Kg and voltage of 4.8V. It has the ability to realize the parallel movements of the gripper, which is driven by a worm that causes the gripper moves away or approach the object, according to the direction of rotation of the servomotor.

The base of the robotic arm was composed of a servomotor (model HSR-8498HB) whose size is 44x20x40mm, weight 52g, with maximum torque of 13Kg (4.8V) - 15kg (6.0V), with a voltage of 4.8V or 6.0 V. These servomotors have the function of supporting the arm and make the movements and times anti-clockwise, allowing mobility and a flexible arm. The other three are part of the respective servo arm joints that have the following characteristics: size 40x20x38mm, weight 39g, 6.5kg torque and voltage of 4.8V or 6.0V "fig.5,6,7" (Table 1) .

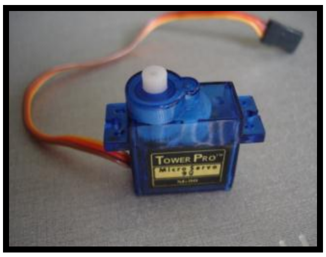


Figure 5: SG90 Servomotor


Figure 6: SG5010 Servomotor

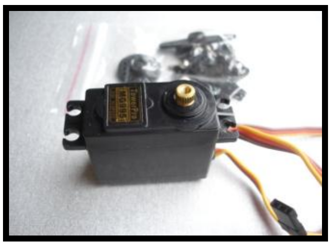


Figure 7: MG995 Servomotor

The arm rods were built with acrylic, and its technical characteristics are: transparency, weather ability, luster, lightness and stiffness. In bonds, the thickness used was two (2) mm and three (3) mm at the base. The gripper and arm base were also built with the same material and all these parts are designed, shaped and cut by laser (DSE Brasil, 2010) "fig.8".

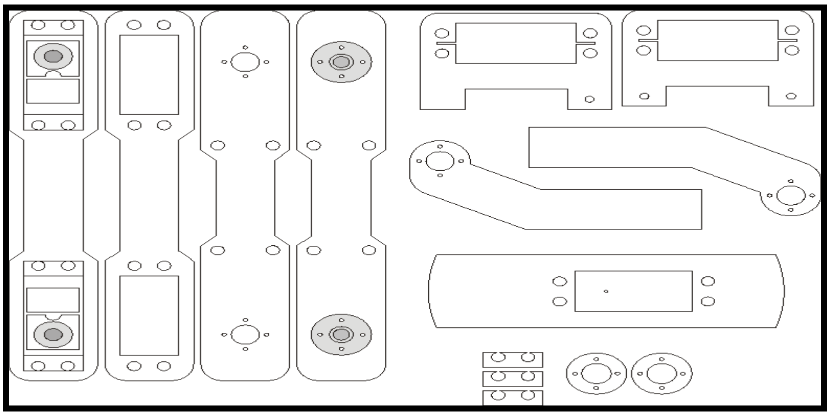


Figure 8: Design of links using acrylic.

The board is designed to control up to 8 (eight) servo via serial, Proteus Ares software being used to simulate the communication between the components. In this case, it was necessary to recreate or scheme of the plate.

The next step, after completing the analysis of the functioning as designed, was to develop the layout of the board for making it. For this project, a plate was selected with double side 100 mm length by 50 mm width. The Proteus Ares was used to organize the components and connections within the selected area “fig.9”.

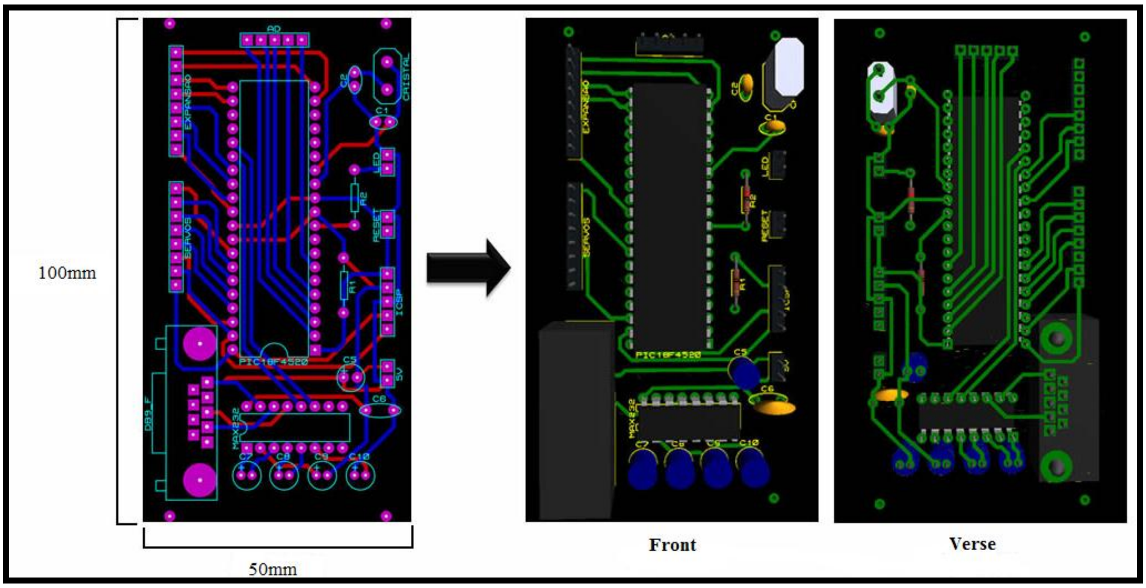


Figure 9: Layout of the interface card between the computer and the arm.

The transfer of the layout for the plate was realized through the laser printing on transfer paper, and its image must be reversed and at the original size. Once the printed circuit was made by washing the plate, for the toner can adhere as desired. The sheet was placed with the printed side down on a piece of copper, and hot iron was pressed on the paper. Once cooled and removed the paper, the card was introduced in the solution of iron perchlorate for copper corrosion, and further cleaning was necessary to remove the ink on the trail. Thus, the making of the board was completed, after drilling with a drill of 0,05 mm and welding the components “fig.10”.

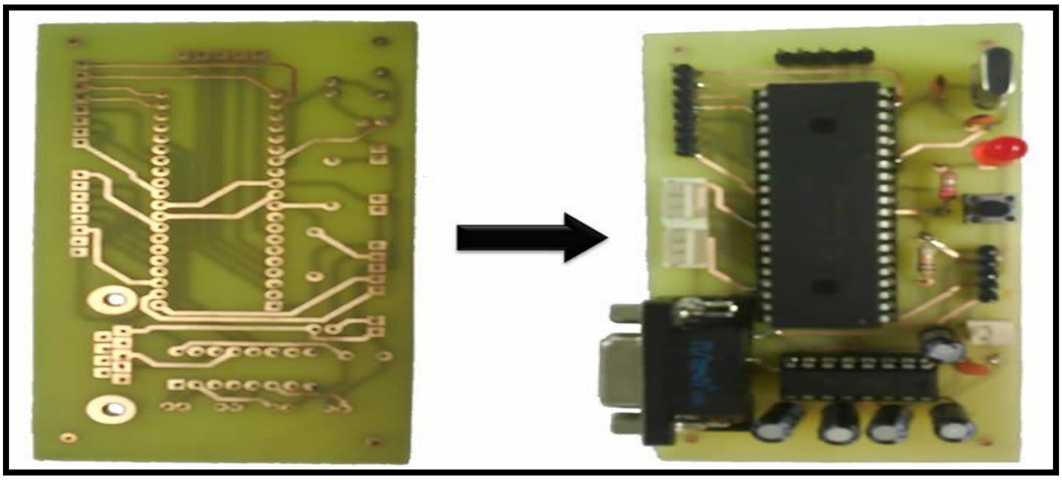


Figure 10: Development of the board.

Table 2 Components used in the manufacture of the plate

Quantity	Type	Value	Reference
1	Reset Button	-	CONN-H2
1	Terminal strip	26 pins	-
1	Crystal	20MHz	CRYSTAL
1	DB9	-	CONN-D9F
1	MAX232	16 pins	MAX232
1	PIC18F4520	40 pin	PIC18F4520
1	LED-RED	-	LED
2	Ceramic Capacitor	10Pf	C1, C2
1	Electrolytic Capacitor	100uF	C5
1	Ceramic Capacitor	100nF	C6
4	Electrolytic Capacitor	1uF	C7-C10
1	Resistor 1/8W	10kΩ	R1
1	Resistor 1/8W	220Ω	R2

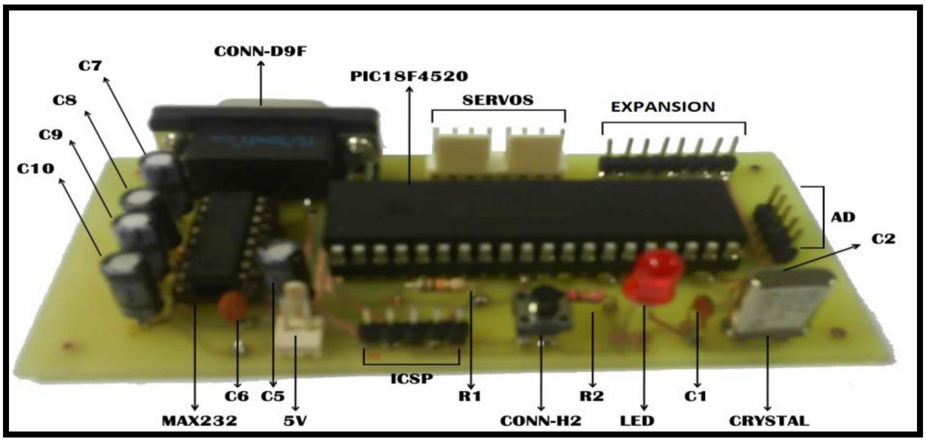


Figure 11: Controller card.

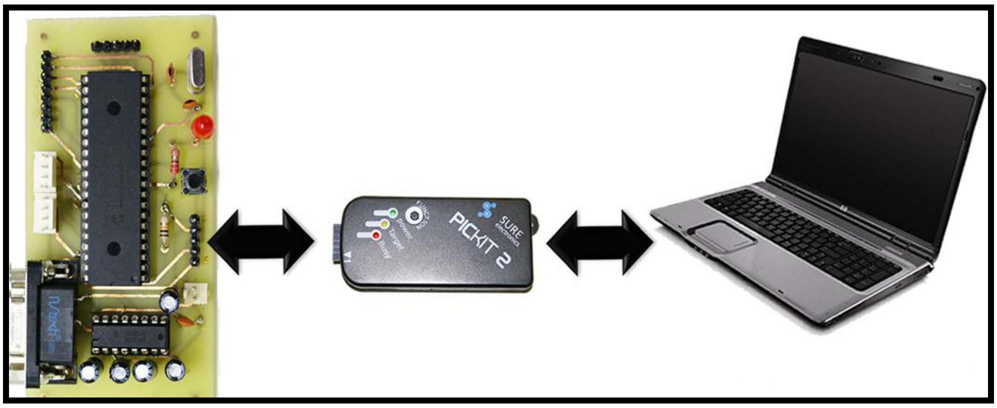
The design printed circuit board contains a PIC18F4520 microcontroller, a transmitter / receiver dual MAX232, some resistors, capacitors, and power supply pins for the analog / digital converter and to connect the PIC to the computer, the servo, and the recorder CIP (Table 2, fig. 11).

We used a voltage of 5V to power the PIC, a 20MHz crystal oscillator to the clock, and MAX232. The MAX232 is an electronic circuit that converts signals from a serial port into signals suitable to use in microprocessor circuits, as used by the PIC levels are TTL levels while the computer is used by the RS232. The gap voltage (up to + / - 12V of RS232 to 5V TTL) is generated by the capacitors.

The PIC18F4520 microcontroller, by Microchip, was used to make the entire control of the robotic arm along with the software. It is a device PDIP (Plastic Dual in Line Package) 40-pin.

To control eight servomotors (five are used and three servomotors effectively used for expansion), eight-pin PIC are configured as output (a pin for each of the waves of the PWM Servo), and communication with the board software is accomplished through the DB9 female connector.

The five identified as ICSP pins are configured for connection with the PIC18F4520 PIC recorder, perform programming and communicating with the servo motors via the USB connection to computer without the need to be removed as part of the plate "fig. 12".



Pin	Signal	Description
Pin 1	V_{pp} / M_{CLR}	Reset Pin Devices / Programming Voltage
Pin 2	V_{dd}	Supply Voltage (2.5 to 5.0 volts)
Pin 3	V_{ss}	Ground or ground potential to PIC
Pin 4	PGD / ICSPDAT	Data signal (input or output)
Pin 5	PGC / ICSPCLC	Data Clock (input or output)
Pin 6	Auxiliary	auxiliary signal (input or output)

Figure12: PIC Writer

Like every all the sensations that we experience are analog as hearing, sight, smell, taste, touch, among others, and the current computer systems such as computers, microprocessors, microcontrollers and other microsystems in general are digital, it is necessary to install a converter to convert any analog signal into a digital signal discrete, liability of being sued by current digital systems.

For this purpose, the pins were inserted and identified with AD. Sensors will be placed on a future project implementation (Dogan Ibrahim).

3.1.1. Interface between the robot and the Computer

The serial port is very useful for controlling devices, interface devices and perform the communication between computers. Because of its simplicity and speed, RS232C interface was chosen to perform the interconnection between the arm and software.

RS232C lines provide a path-way, point by point, for a distance of up to 15.24 m at a transmission rate of 20Kb/ s.

4. PROGRAMMING

In this design, the program performed to drive the servo was divided into two parts. The first is characterized by the combination of commands to be sent to move about one degree for each engine, by programming the PIC 18F4520 installed on the board. The second is the implementation of the software installed on the computer, with programming in C++, which through its connection with the board, shall send various commands to the PIC in order to move the gripper to the desired object, and select it (Pereira, 2006).

4.1. Interface between Robot and Software

The serial port is very useful for controlling devices, interface devices and perform the communication between computers due to its simplicity and speed, and the RS232C interface was chosen to perform the interconnection between the arm and software.

The RS232 communication is at type of full duplex point to point, up to a distance of 15.24 meters at a baud rate of 20Kb / s, because we have only one line of transmission and reception of only one. Thus, while we are transmitting a byte of the TX line, we may well be getting another for the RX line.

All serial communication, like USB, RS485 or RS232 uses a communication rate (baud rate). With the baud rate, we know how many bits can travel on the line in an interval of 1 second. Normally, the baud rates are multiples of 300bps (bits per second), so finding communication rates such as 2400bps, 4800bps and 9600bps. In the project the rate used was 9600bps.

5.0. CONCLUSION

As science fiction stimulates the development of new technologies and increasingly specialized professionals, this paper aims to present a platform for studies to arouse students' interest and improve their knowledge through the application of aggregated contents acquired in the course subjects.

The structure of the robotic arm held three degrees of freedom was composed of acrylic base, joints, linkages and gripper. The base and the joints are responsible for the servo turns clockwise and counterclockwise in a straight up, down, right and left. The grippers are responsible to pick up, secure and transport the object from one point to another, as well as offering a servomotor to open it and close it.

To control the robot's movements it has been developed for a plate of the servo control by programming the PIC 18F4520, and building software programmed in C for insertion of shares to be sent from computer to the board through the USB / RS232 converter cable.

Thus, we describe all steps required for the development of robot manipulator, adding theoretical information about the technology involved.

During the project, some difficulties were identified in the simulator's programming of PIC, the servo motors used in the structure of the arm, and its movement.

In the simulation of the PIC programming the software used was Proteus, but it should be undertaken further study of its resources. We identified a few bugs, such as the incompatibility of the version used with the operating system, which can delay progress of the project.

At the time of feed servo there is a sudden shift to the first angle (0x01), and it can result in broken engines. Moreover, the servomotor used in the shoulder showed no support structure of the arm angles very close to the base.

The structure of the arm had trepidations during movement of the servants, indicating the necessity of better stability. During movement, the arm had crashes that should be corrected by changing the programming code of the PIC, through the implementation of flow control in serial communication.

For improving the mechanical arm, some changes that should be implemented in future projects are outlined below

- Use better quality servants and greater torque;
- Greater thickness of the acrylic used in the body (greater than 4 mm);
- Adjust the PIC code;
- Implement proximity sensors (mainly for gripper) and flow control;
- Use a PIC with USB communication, avoiding potential problems with driver converter cable (USB-RS232);
- Improve stability by increasing the diameter of the axis of fixation and decrease the dimensions of the links.

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