THE REMANUFACTURING OF AN ARTICULATED ARM ROBOT WITH 5 DEGREES OF FREEDOM STEP IN THE ACADEMIC PRACTICAL EXPERIENCE

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Rezumat. *În cadrul acestui proiect s-a urmărit procesul de refabricare a unui robot didactic de tip braț articulat, cu 5 grade de libertate. Scopul final al proiectului este realizarea unui model didactic funcțional, programabil și simplu de utilizat și înțeles de către alți studenți. În urmărirea acestui scop, se prezintă aici primele întâlniri atât cu reprezentanții industriei de profil din Romania, cât și cu furnizorii pentru diferite componente. Prin finalitatea proiectului se afirmă necesitatea următoarelor: planificare riguroasa a riscurilor, planificare a etapei de dezasamblare a proiectului și recuperare de componente, experiența câștigata în afara programului de studiu.*

Abstract. *In this project we aimed at the remanufacturing process of a teaching robot with an articulated arm and five degrees of freedom. The ultimate goal of the project is to develop a functional didactic model, programmable and easy to use and understand by other students. In the pursuit of this goal, we will present to you here the first meetings with the industry representatives from Romania and suppliers for various components. The stated purposes of the project show the necessity of: planning a rigorous stage of disassembly and recovery of components, the experience gained outside the normal academic program, rigorous planning for risk, rigorous timetable planning.*

Keywords: remanufacturing**,** project planning, articulated arm robot, electronics

1. Introduction

The necessity of a working teaching model in a learning institution cannot be stressed enough. As well, the importance of a simple and easy to understand model for young, inexperienced students, is almost vital for the learning process.

As such, the current project has the goal set at offering back a working, programmable device, that can be worked on by just about anyone who has an interest in it. Alongside the physical model, it will offer upon its completion a detailed report on both the construction of the robot, and the experience gained along the road. This experience, a valuable resource for any student, will include data about manufacturers of components, retailers, the importance of having a risk management plan and also the importance of having a recycling plan for the end of the device's lifecycle. Such aspects, as though during college years, have a great importance and relevance in the industry; but it is only through experience that these can be truly appreciated, and it is our interest to pass on this knowledge, in an accessible way.

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2. Articulated arm robot

It is difficult to compare numbers of robots in different countries, since there are different definitions of what a "robot" is. The International Organization for Standardization gives a definition of robot in ISO 8373: "an automatically controlled, reprogrammable, multipurpose, manipulator programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications." This definition is used by the International Federation of Robotics, the European Robotics Research Network (EURON), and many national standards committees.

Particularly, the project is about the remanufacturing of an articulated robot, with 5 degrees of freedom, all of them rotations (fig. 1.): 3 for positioning system and 2 for orientation system. We have started from the existing robot structure (fig. 2. a) form University ”Politehnica” of Bucharest.

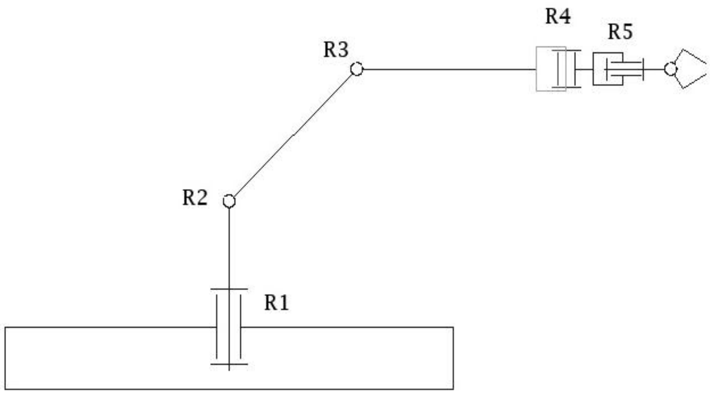

Fig. 1. Cinematic representation of the robot.

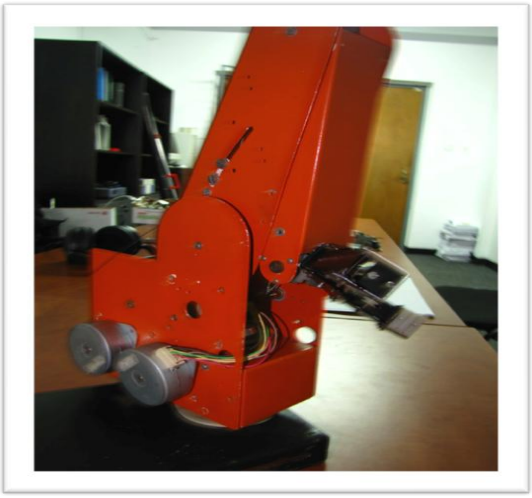

Fig. 2. Remanufacturing the articulated arm robot.

We have made a redesign of the robot parts in a CAD software. Also we have designed the new components needed (fig. 3). The 3D models of the parts were created and assembled in CATIA V5 software. Making scale 3D models of the existing parts help us to design the new optimal elements to complete the robot remanufacturing.

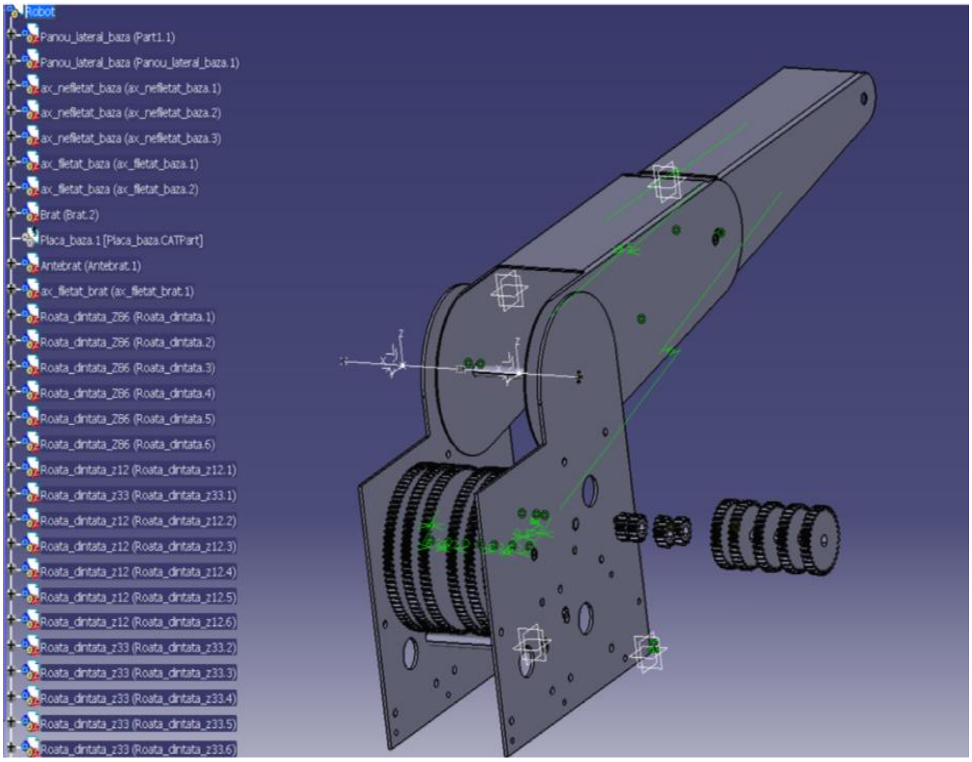

Fig. 3. Catia 3D design (no gripper).

3. Project planning

Having developed the idea for the project, the first and most important stage for us at the time had been the development of a timetable. We had great estimates for the risks of such a project, and the length of time it would take for us to complete our tasks.

In the first step the total time for the project was predicted at little over a month, most tasks being simplified or unified with others of little importance, so as to meet this criterion of time.

With the help of information acquired during "Project management" courses, the risks for the project had been estimated to offer a minimal resistance for its progress. Each risk had been calculated to not delay work for more than three days a time, and that was the extreme (fig. 4).

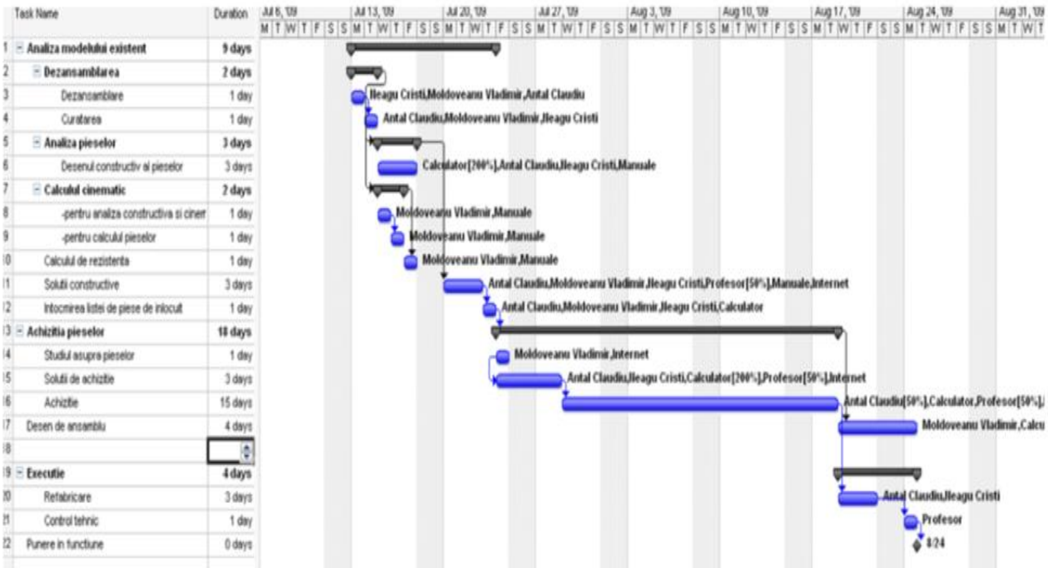

Fig. 4. Project planning in Microsoft project.

4. Problems and solutions in project development

As a first stage for the project had been set to acquisitions of materials that could not have been manufactured internally, in the faculty, efforts had been concentrated on seeking out these. Many problems that had to be faced, and now taken into account in a new planning session had been:

- Scarcity of components and materials, especially electrical;
- Suppliers that kept small quantities on stock and henceforth we needed to make special orders for small components, such as gears or connectors;
- The inaccessibility of some of the components that were needed, to the point of having to order them from abroad, thus lengthening the development process;
- Lack of professionalism towards students, cold receptions from many suppliers and even dismissive attitudes.

In these condition the initial (ideal) project planning had become obsolete even in the very first stages of the project, prompting a reevaluation of the entire process. This led to accentuating the following aspects:

- The need for detailed market studies;
- The need for acquiring alternative solutions;
- Stricter risk planning, with realistic timetables for various activities, now to include objective problems like college programs and activities;
- The need to plan for the life cycle end, to incorporate recycling tactics into the foundation of the project.

Alternative solutions had been found for a number of problems in recycling old equipment to suit new needs. As such, a number of printers had been stripped for the stepper motors they had in their construction, as well as other parts like gears, micro switches and transmission belts.

This also convinced us of the importance of having a modular built system, as it would greatly simplify the recovery of various components that may still prove useful after the robot ceases to be.

We also resorted to ordering components from on-line suppliers, many of which necessitating a long time for them to arrive. But it proved more accurate and these delays had been counter balanced by the boost in precision.

5. Rebuilding the robot

5.1. The mechanical part

The first step that was undertaken was to disassemble the mechanical structure and replace most of the elements that had been worn out by time. As such, we had the base of the robot machined of oxidation and excess paint, the transmission cables replaced and had added new gears. The power transfer from the motors to the movement joints would be assured via a series of reducing gears, of which we had acquired new pinions.

Each stepper motor assures the movement of one joint, and one for clenching the gripper at the end of the cinematic chain. There are 6 motors in all, everyone recuperated from office equipment.

At the base of the robot there two *axial* ball bearings, set to ease the base rotation of the device. These have been cleaned of dust and grime, and lubricated again for a better performance.

As previously stated, solutions had to be improvised. As the ax for one of the motors proved too short for our needs, an extension had to be manufactured.

5.2. The electronic part

The electronic part of this robot is made of the following: power supply; power delivery board; six motor drivers; a microcontroller board.

The power supply consists of a toroidal transform, supplied with 220 VAC (standard mains voltage). It then outputs 2×18 V RMS (24 VDC after rectification). One side of the transform is used to power 3 of the motors, and the other the other 3 motors, as well as the logic circuits.

The job of the power delivery board is to convert the 24 V it receives from the power supply into various voltages used by different components (8 V for the microcontroller, 15 V for the motor drivers, etc.).

The microcontroller is, however, not custom made. The “brain” of the controller board is an ATmega 640, produced by Atmel. It has a clock speed of 16 MHz and hardware PWM clock generators, which make it well suited for the application at hand.

The reason in choosing this controller board instead of a more traditional PLC is its cost/capability ratio. While relatively cheap, it has in excess of 40 I/O ports, and 16 10 bit ADC channels. It is well suited for controlling several devices at once, and to process signals from a wide array of sensor types (from presence sensors or micro switches, to encoders of all kinds, and even GPS receivers). Also, the software used to program it is free, a fact which cannot be said about PLC software.

With that being said about the controller board, the design idea behind this project should be apparent. From the conception stages, the electronics were meant to not only control the robot itself, but also additional equipment that works in relation with the robot, and even a completely different application (as long as it makes use of stepper motors) (fig. 5). It is meant to provide a hardware platform on which students can start learning how to program robots or automated production lines in industrial environments.

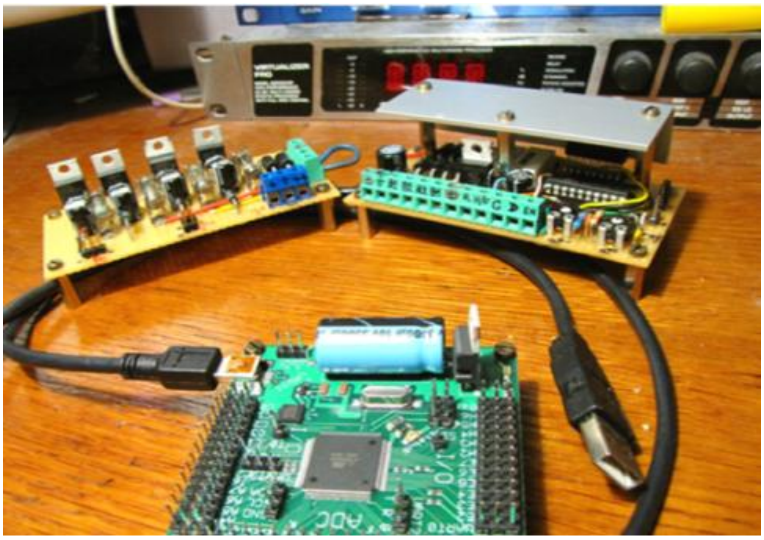

Fig. 5. Electronic component produced in-house.

The L298 is a dual H-bridge driver. While the L297 represents the low power logic stage, the L298 is the high power drive stage. It is capable of driving unipolar and bipolar stepper motors with up to 2 A current draw. Usually, a stepper motor that draws 2 A of power is capable of 1.5 – 2 Nm of torque. This allows for further improvement in the robots structure in the form of more powerful motors.

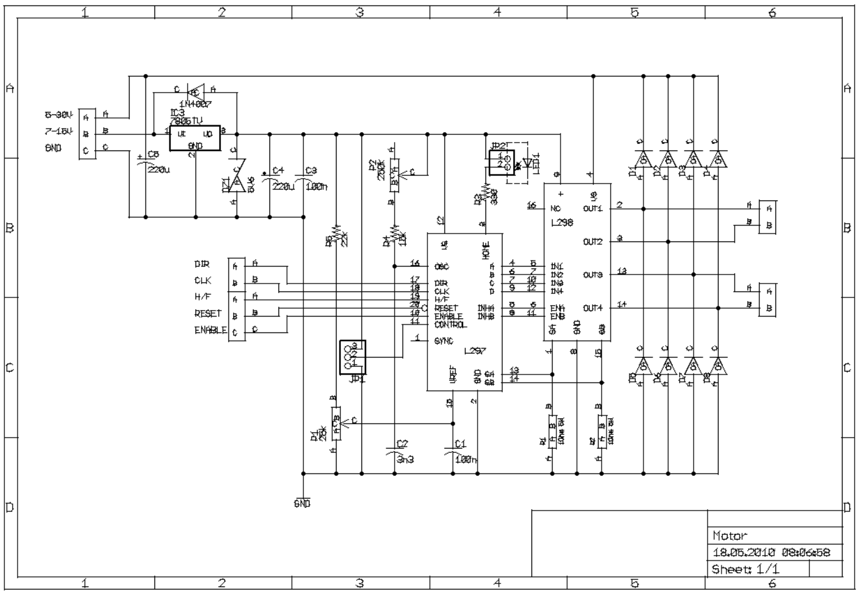

Fig.6. Circuit design for the motor drivers

5.3. The programming

The actual software writing process is very user friendly. The language employed is ANSI C. The IDE used for project development is AVR Studio, available without charge from Atmel's website.

Since the user base for the Atmel AVR processor series is so wide, software libraries have been developed to facilitate software development. The most complete and user friendly one is Clive "Webbot" Webster's library. It makes programming the controller of our robot an almost trivial affair.

Also made by Clive Webster is the Project Designer. A Java based application that creates all the hardware specifications and initializations for the user. With its help, adding I/O ports, PWM clock generators or ADC channels is done via drag-and-drop.

Using the tools at hand, relatively complex programs can be done by complete beginners in a matter of hours. It is just a matter of telling the Project Designer where different devices connect on the controller, and then, using AVR Studio, writing the actual program. This process replaces abstract calls to I/O ports with literal expressions (i.e. replacing _SFR_MEM8(port) |= mask; with pin_high(enable);).

All these tools are meant to help a student get comfortable with the hardware platform and the development process, allowing him to focus on designing the process.

Conclusions

These projects offer us the experiences need to develop an industrial project even if we were working in the educational level.

All the logistics and financial requirements were offer by the National Center for research of the performances of the technological systems –Optimum from the University POLITEHNICA from Bucharest. (http://sun.cfic.pub.ro)

The goal of our project was to develop an articulated arm robot with 5 degree of freedom in order to be used in the learning process. The robot can be used from application and/or from the programming point of view.

The use of the robots doesn't represent any risk for inexperienced students concerning the dimensions of the robot and its technical characteristics. The principles of programming and implementation into application are the same with the one in the industrial environments.

There is room for expansion built into the design. If a student decides that he rather use the ports reserved for the remote control to send or receive some other kind of signal, it can be done; or if he decides that he would like to add a translation at the base of the robot, he can. It is meant to be a very flexible design.

The design of the robot controller follows the main idea: giving young students an opportunity to learn robot programming, modular design and electronic design.

The three parts of a robot – mechanical body, electronic brain, software soul – need to coexist for a robot to function properly.

The perspectives for us are to develop the final project based on this one in order to obtain our license degree in University POLITEHNICA from Bucharest. We want to create a fully integrated flexible mini-production system by using this robots linked with another one and FESTO translating modules.

R E F E R E N C E S

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