TECHNISCHE UNIVERSITÄT
ILMENAU

50. Internationales
Wissenschaftliches Kolloquium

September, 19-23, 2005

Maschinenbau von Makro bis Nano / Mechanical Engineering from Macro to Nano

Proceedings

Fakultät für Maschinenbau /
Faculty of Mechanical Engineering

Startseite / Index:
http://www.db-thueringen.de/servlets/DocumentServlet?id=15745

Impressum

Herausgeber:	Der Rektor der Technischen Universität Ilmenau Univ.-Prof. Dr. rer. nat. habil. Peter Scharff
Redaktion:	Referat Marketing und Studentische Angelegenheiten Andrea Schneider Fakultät für Maschinenbau Univ.-Prof. Dr.-Ing. habil. Peter Kurtz, Univ.-Prof. Dipl.-Ing. Dr. med. (habil.) Hartmut Witte, Univ.-Prof. Dr.-Ing. habil. Gerhard Linß, Dr.-Ing. Beate Schlütter, Dipl.-Biol. Danja Voges, Dipl.-Ing. Jörg Mämpel, Dipl.-Ing. Susanne Töpfer, Dipl.-Ing. Silke Stauche
Redaktionsschluss: (CD-Rom-Ausgabe)	31. August 2005
Technische Realisierung: (CD-Rom-Ausgabe)	Institut für Medientechnik an der TU Ilmenau Dipl.-Ing. Christian Weigel Dipl.-Ing. Helge Drumm Dipl.-Ing. Marco Albrecht
Technische Realisierung: (Online-Ausgabe)	Universitätsbibliothek Ilmenau ilmedia Postfach 10 05 65 98684 Ilmenau
Verlag:	isle Verlag ISLE, Betriebsstätte des ISLE e.V. Werner-von-Siemens-Str. 16 98693 Ilmenau

ISBN (Druckausgabe):	3-932633-98-9	(978-3-932633-98-0)
ISBN (CD-Rom-Ausgabe):	3-932633-99-7	(978-3-932633-99-7)

Startseite / Index:
http://www.db-thueringen.de/servlets/DocumentServlet?id=15745

50. Internationales Wissenschaftliches Kolloquium
Technische Universität Ilmenau
19.-23. September 2005

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Walking Minirobots

ABSTRACT

The walking robots degrade less the environment and have a higher mobility than those that have wheels or caterpillar chains. The paper presents some walking robots controlled by means of a computer. The minirobots have been made like experimental models at the Precision Mechanics and Mechatronics Department from the Politehnica University of Bucharest.

MECHANICAL STRUCTURE OF THE DESIGNED MODELS

The world of biological beings presents enough motives of inspiration for conceiving technical models of robots or walking minirobots.

As a rule, a mobile robot, especially a walking one, is inspired from the world of the biological beings). These robots are used in several fields like military (e.g. out of working of the mine field), extraterrestrial (e.g. exploration of other planet), nuclear, aquatic, geological, archeological, other utilities (e.g. pipes and reservoirs cleaning, fire extinction).

A first model of minirobot designed and built by the authors of this paper is represented in fig.1. The minirobot is actuated by means of some pneumatic actuators represented by pneumatic

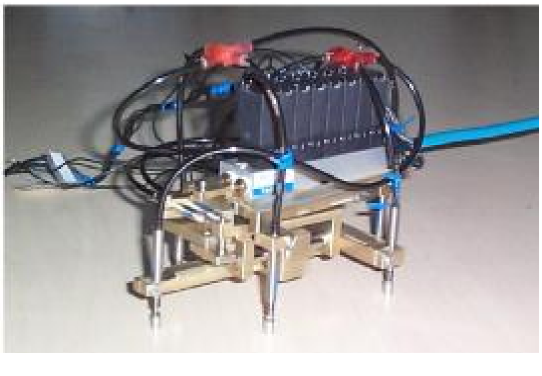

Fig. 1. View of the pneumatic minirobot

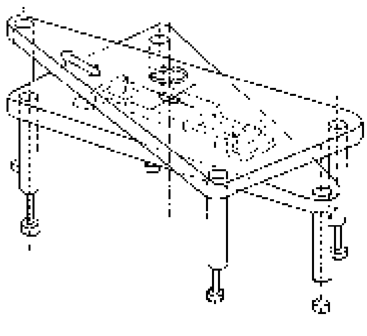

Fig. 2. The schematic representation of the minirobot

single effect minicylinders. The minirobot (fig. 2) consists of two platforms, placed one over the other, either of them having three pneumatic cylinders which materialize a translation motion on a horizontal axis. Moreover, the platforms have the possibility to perform two relative displacements, a translation motion on a horizontal axis and a rotation motion around a vertical axis. In order to materialize the translation motion, two guiding columns, which are fixed on the lower platform, have been provided. A cylindrical bearing is mounted between the slide plate and the upper platform in order to materialize the rotation motion.

The movement of the robot in plane is possible by repeating nine defined motion types, which are as follows: straightforward, right-forward, left-forward, straight-backward, right-backward, left-backward, right-pivoting, left-pivoting and upward/downward movement of the platforms.

The motion types are achieved by controlled sequences of certain elementary displacements. An elementary displacement is achieved when the mobile parts of the minirobot are actuated by one pneumatic cylinder. In the first step of the project development it has been considered that the cylinders which stand for the legs of the minirobot work together in two groups of three cylinders. In this case the defined elementary displacements are the following:

- an upward/downward translation motion of the upper platform, achieved by means of three pneumatic cylinders group C_1, C_2, C_3 (noted C');

- an upward/downward translation motion of the lower platform, achieved by means of three pneumatic cylinders group C_4, C_5, C_6 (noted C");

- a forward/backward relative translation motion of the platforms, achieved by means of a pneumatic cylinder $C_{7;}$

- a right relative rotation motion of the platforms, achieved by means of a pneumatic cylinder C_8;

- a left relative rotation motion of the platforms, achieved by means of a pneumatic cylinder C_9.

For example, fig. 3 and table 1 show the elementary displacement sequences for the straight-forward motion type of the minirobot.

For continuous movement among the motion types it was adopted the condition that all of them are finished with the sixth displacement shown in table 1.

For the proper working of the minirobot must be determined the optimum frequencies of the elementary displacements. These frequencies were experimentally determined and depend on the inertia of the minirobot mobile parts, the dynamic response of the pneumatic cylinders and of the directional control valves belonging to them and the requested velocity.

Table 1

Displace-ment	Cylinders				
	C_9	C_8	C_7	C'	C"
1	0	0	0	0	1
2	0	0	1	0	1
3	0	0	1	1	1
4	0	0	1	1	0
5	0	0	0	1	0
6	0	0	0	1	1
0 – no-powered cylinder; 1 – powered cylinder					

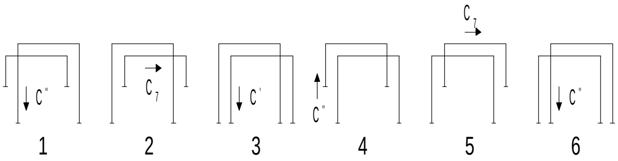

Fig. 3. Elementary displacement sequences

Other two models of minirobots, represented in Fig. 4 and Fig. 5, are actuated by electrical step by step motor-driven gears (motor reduction units).

The first model of minirobot (fig. 4) moves by crawling. For moving in a straight-line direction, it is endowed with soles of special, pre-formed brushes that slide on the working surface (excepting the usual sole) at the moving in one sense or catch it in the other sense. In order to change the moving direction, it must modify the relative position between the carcass of motor-driven reductor (7) and the holder (9).

Another designed minirobot (fig. 5) is the hexapod model of spider type. The eight legs of the insect-minirobot execute tilting movements of ω_1 and ω_2 – angular velocities around the axes. One of them is the vertical axis, normal to surface. The minirobot leans every time upon four legs at least, so being ensured the stability of the robot during the movement. For this purpose, the ends of the legs situated on the same side of the robot will be successively mounted in the opposing bores (diametral opposed) of the driving gears.

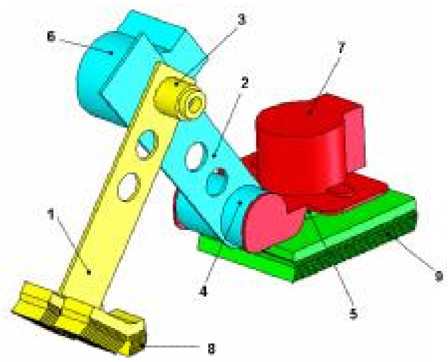

Fig. 4. Component module of the worm minirobot

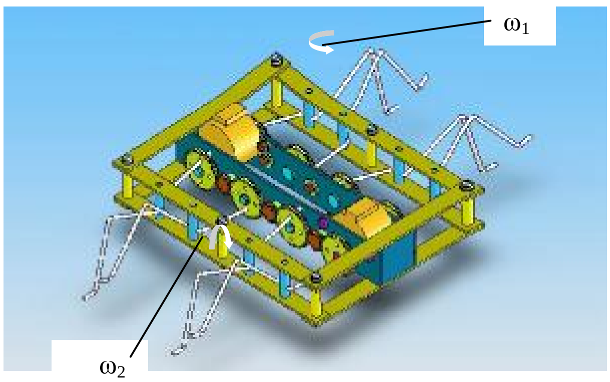

Fig. 5. Hexapod minirobot of spider type

THE CONTROL OF THE MINIROBOTS

The control system of the pneumatical minirobot is shown in fig. 6 and consists of the personal computer 1, which runs the application program 2, the data acquisition board 3, the electronic circuit 4 and the directional control valves of the pneumatic cylinders 5.

The electronic circuit is used to amplify the signals sent to the electromagnets of the directional control valves, provided by five digital outputs of the data acquisition board.

The electromagnets and therefore the pneumatic cylinders are connected to the digital outputs (DO) of the data acquisition board in the following configuration: C" to DO0, C' to DO1, C_7 to DO2, C_8 to DO3, C_9 to DO4.

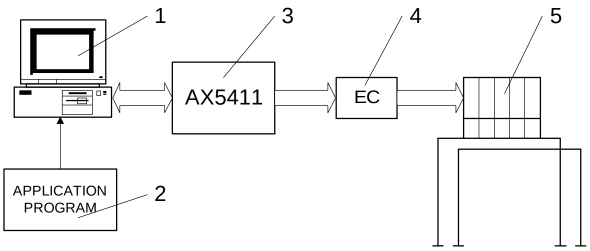

Fig. 6. The walking minirobot control system

For the beginning it was used a data acquisition board AX5411 (Axion Company).

The application program that controls the walking robot motion was written in Pascal language.

In other stage it was used the parallel port of the computer and the Labview Software. An interface was used as a power amplifier. The power amplifier has been made using an ULN2803 Darlington transistor array which consists of 8 npn Darlington pairs with a collector-current rating of each pair of 500 mA, being a very good choice as an interface between the low level logic circuits and the power circuits.

The pneumatic minirobot can be controlled in two ways, as follows: by manual controls (step by step) or by groups of controls in the form of a program.

For each type of control there is a frontal panel - as shown in the following pictures - having in common only the way of setting the memory address of the parallel port and of the working frequency.

Fig.7 shows the frontal panel for manual controls. The displacing possibilities are indicated by arrows placed next to the buttons which determines the motion towards that direction as long as they are pressed.

Fig.8 shows the panel for the case in which the robot is controlled by a sequence of commands in the form of a number of steps and a direction of motion.. The controls sequence is specified in the left part of the panel. In order to start to perform the commands the button OK has to be pressed.

To each direction corresponds a group of 2 letters showed in the right central part.

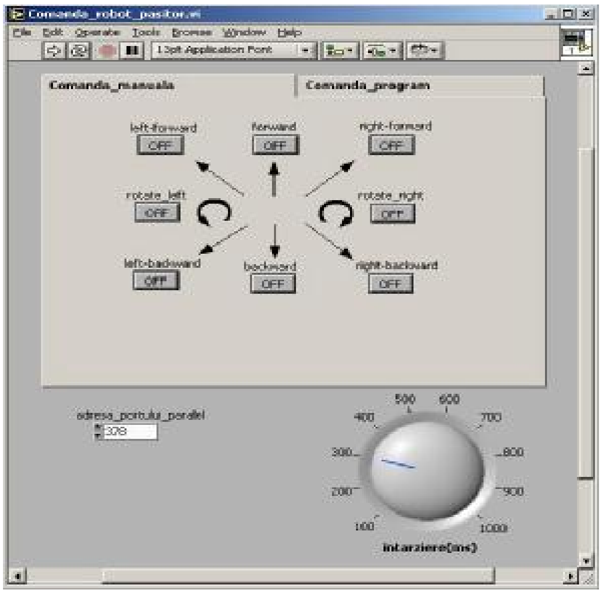

Fig. 7. The frontal panel for manual control

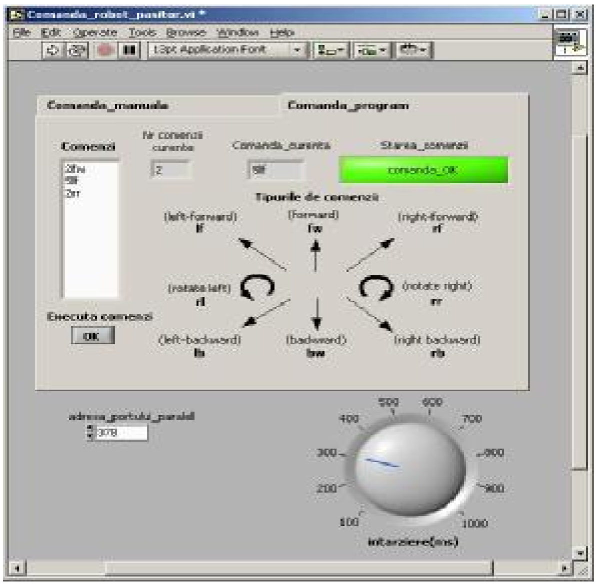

Fig. 8. The frontal panel for sequence control

After the commands are initiated, in the upper part are shown some fields in which there are indicated the number of the current command line, the command content and the state of the current command.

When the specified command is not among the indicated ones or when it is reached the end of the commands set, the program stops and the user is informed of this by the last field. In order to start the program again is necessary to press the Ok button again, just after the wrong command has been corrected.

The control of frequency, similar for the two panels, offers the possibility of setting the delay time for the component movements of each command. This time is set depending of the application. A very short time results in a heavily mechanical loading of the robot while a long one in low speed displacements.

Below are presented the diagrams for the two control modalities. In fig. 9 is presented the diagram for the manual control of the minirobot (step by step). Pushing of one of the eight buttons corresponding to the different moving directions, leads to the selection of the moving sequence necessary in performing of a step in that direction.

Thus, in the selection block there are eight cycles “FOR” corresponding to the basic displacements of the minirobot.

Fig. 10 represents the diagram corresponding to the time command of the program. This modality is based too, on the step by step actuation logic to which has been added the possibility of recognition and interpreting of the command lines from the working sequence indicated by

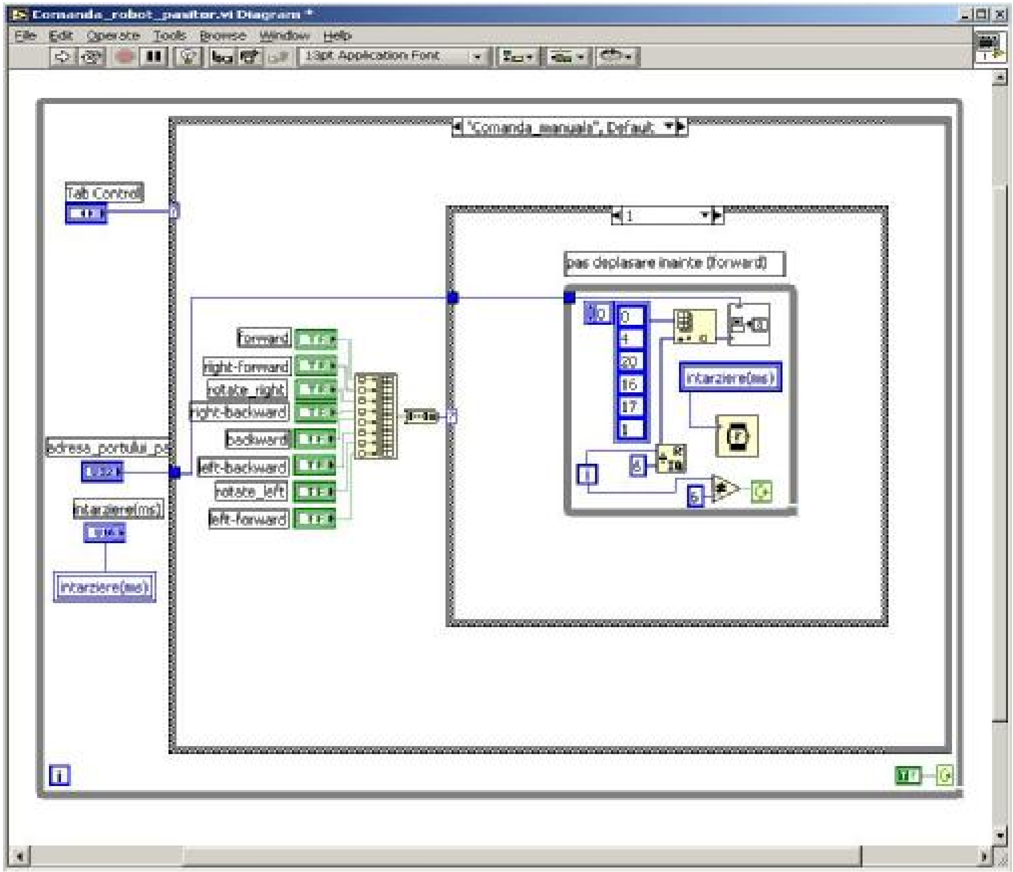

Fig. 9. The diagram for the manual control

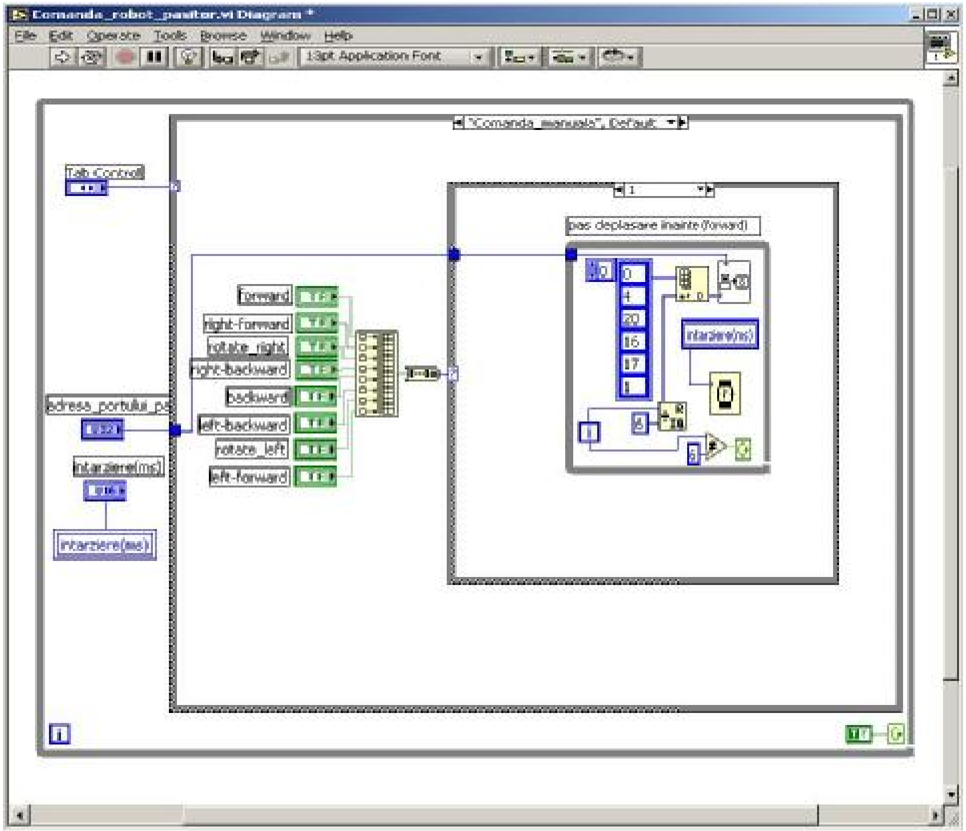

Fig. 10. The diagram for sequence control

the user and also the signalling of a line which is not part of the possible commands and of the end of the program.

For the two models of minirobots actuated with step by step gearedmotors and controlled with a PC it has been used an identical as the one from fig. 6.

The control of the minirobots is done through a data acquisition board LAB-PC-1200 (from National Instruments). Between PC 1 and minirobot 5 is interposed the data acquisition board 3 and the power circuit 4 for the control of the step by step motors (MPP) .

In fig. 11 are presented the connections of the acquisition board LAB-PC-1200.

The diagram for the interface, presented in fig. 12, customized for the worm type minirobot, shows the placement of the transistor and its functions:

- to translate the voltage from 5V given by the acquisition board to 12 V necessary for the actuator;
- to allow a higher current than the maximum given by the acquisition board in order to actuate the motors;

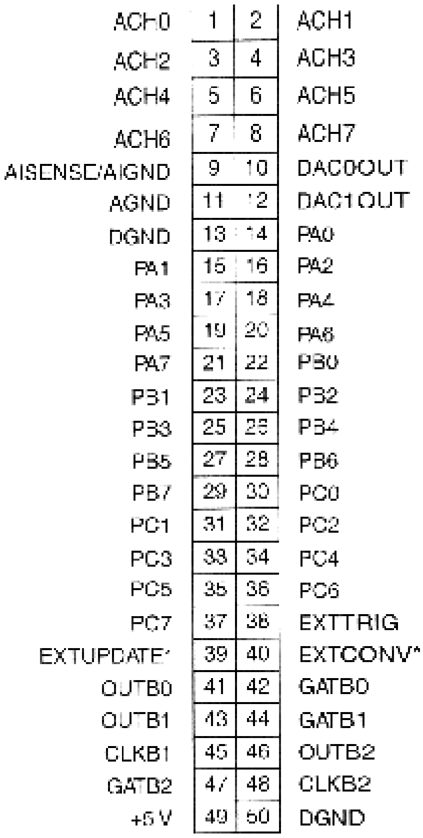

Fig. 11. The connexions of the acquisition board

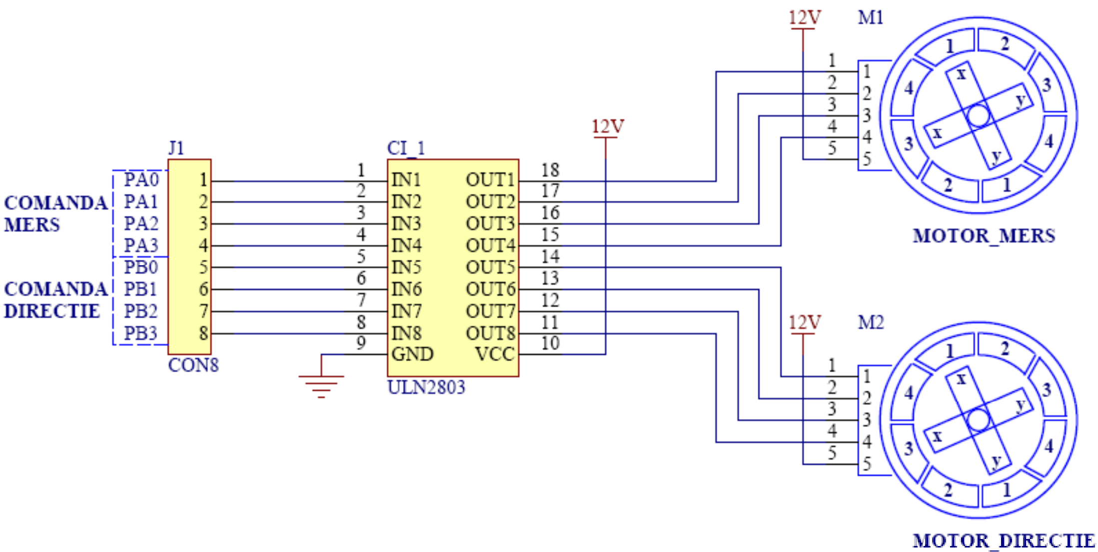

Fig. 12. The power amplifier interface for two step by step motors

- to protect the acquisition board.

The program used for the minirobot control has been LabView.

In fig. 13 is presented the control panel of the minirobot done using LabView.

Activation or the deactivation of the whole panel can be done from the „START/STOP” button.

Once the control has been activated through the command panel, this offers the user the independent control of the two step by step motors.

From the button ”Mot mers Pornit/Oprit” it is activated/deactivated the actuation of the motor used for moving the robot in a chosen direction and from ”Mot directie Pornit/Oprit” it is activated/deactivated the controls over the motor used in directing the motion.

There are also, the buttons „Sens – Direcție” and „Sens – Mers” from which it is possible to change the rotation direction for each step by step motor of the minirobot, which allows for forward and backward movements and also for returning to the previous direction of motion.

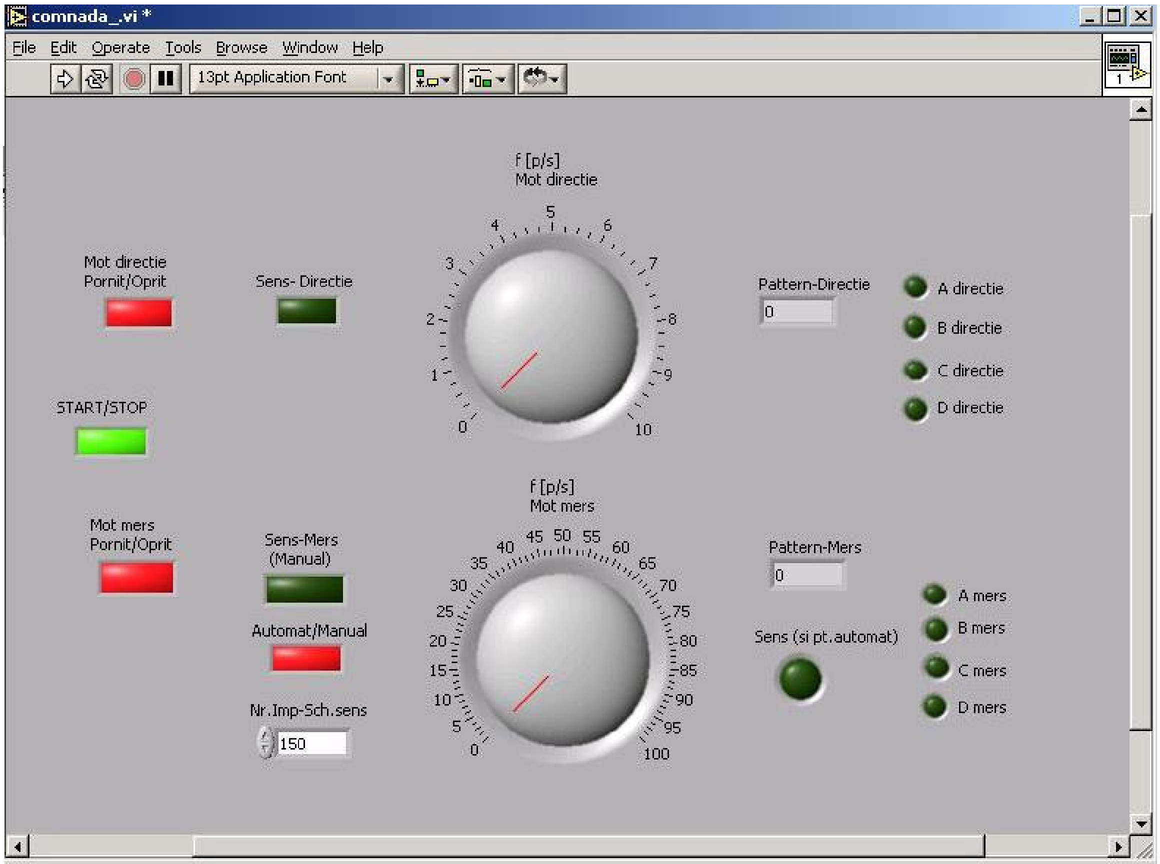

Fig. 13. The frontal panel for minirobot control

The field „Nr. Imp - Sch. Sens” will be filled in with the value of the angle between the elements 1 and 2 (see fig. 4) expressed by the number of the consecutive phases necessary to be supplied for its execution.

In the field „Pattern – Mers” or „Pattern – Direcţie” can be read the number of the steps (corresponding to the number of supplied phases) performed by each step by step motors of the minirobot during the current cycle. This allows to extract, for the direction motor, the number of steps necessary for performing of the angle desired to be used in the translation motion (see fig. 4).

In the case of the control of the motor which assures the movement of the motor towards a direction, the user has the possibility to use another buton named ”Automat/Manual” by which action the motor is switched to automatic control, in forward and backward cycles, each of them containing the number of steps indicated by the user in the field ”Nr.Imp - Sch. Sens”. In this way it is assured the automatic motion of the minirobot to one direction.

On the panel, there are also presented for each motor four indicators (A-D) for the supply of each phases.

In fig. 14 is shown the logic diagram (block) for the program with which the command is sent to the acquisition board Lab-PC 1200.

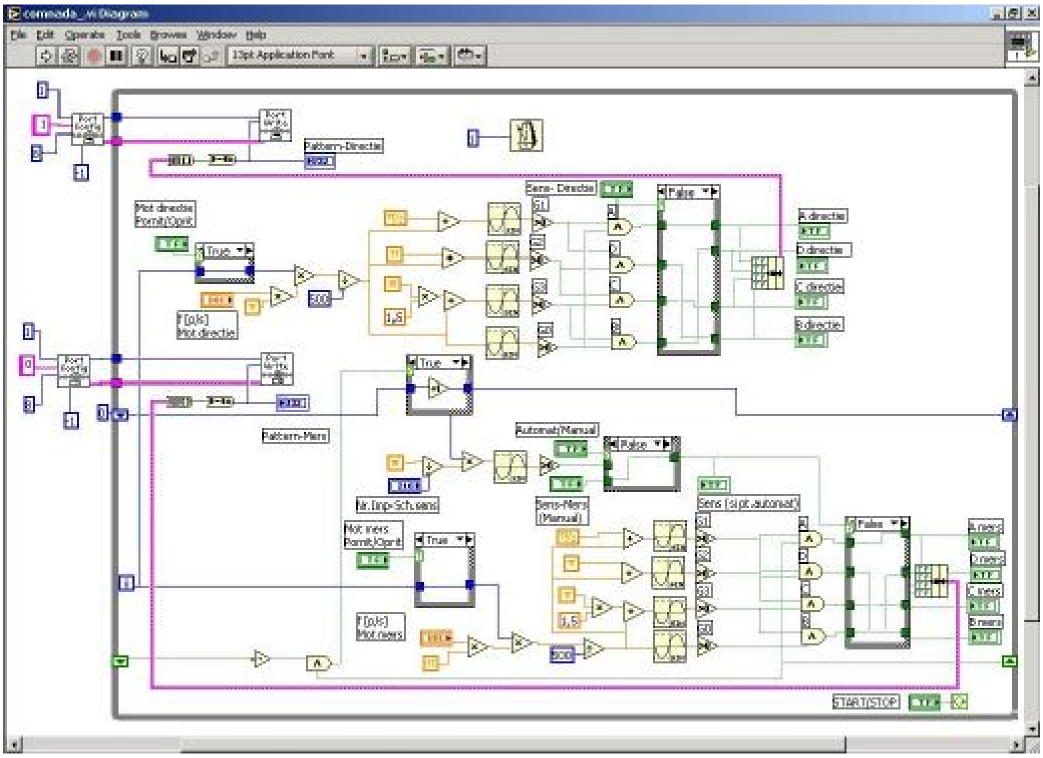

Fig. 14. The diagram of the control program of the minirobot

Each motor is actuated independently through a Start/Stop button, and a button for the direction of motion of each motor.

For each motors there are two almost similar blocks.

One motor is attached to the port PA of the board and uses the slots PA0-PA3. The other motor is attached to the port PB of the board and uses the slots PB0-PB3. The ports are set as outputs.

The program gives the user the possibility for an automatic control in which after the number of pulses for one displacement is set, the minirobot can move with one step corresponding to the number of the pulses set by the user.

CONCLUSION

Designing the minirobots presented in this paper, the authors intend to perform some kits that allow their use in both preschool educational process and the labs from pre-university and university education.

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