11th International Research/Expert Conference
”Trends in the Development of Machinery and Associated Technology”
TMT 2007, Hammamet, Tunisia, 05-09 September, 2007.

MANIPULATOR USED IN A MICROFACTORY

Ion Lungu, Csibi Vencel
Technical University of Cluj-Napoca, Faculty of Mechanics
B-dul Muncii, no. 103-105, 400641, Cluj-Napoca
Romania

ABSTRACT
This paper contains four parts. In the first parts, what is a microfactory and significance of the minirobot in the structure of a microfactory are describe. The second paragraph presents direct kinematics of the manipulator. In the next one, the mechanical structure it is described. In the fourth part the electrical diagram and control methods to actuate the minirobot are presented. Several technical details concerning to the design of electrical diagram, layout and control method are given. Finally, the most important conclusions and future work are emphasized.
Keywords: microfactory, manipulator, manufacturing.

1. INTRODUCTION
Microfabrication technologies have been steadily advancing in recent times. Research and development are being vigorously conducted with a view toward the implementation of micromachines. The use of micromachines is likely to increase, and they will become more closely related to our daily lives. The microfactory is a small manufacturing system for achieving higher throughput with less space and reduced consumption of both resources and energy via downsizing of production processes. The term microfactory represents an entirely new approach to design and manufacture that minimizes production systems to match the size of the parts they produce [1].

The basic concept of the microfactory is “What better way to make small parts than with a small machine?”, [2]. If it is possible to manufacture equipment and production system smaller, far fewer resources will be needed to make the machines themselves and far less energy will be required to run them. Noise, vibration and pollution can be reduced a lot which can make factories environmentally-friendly. This thrust of scientist and researcher lead to small size production system termed as microfactory, [3].

The microfactories equipments and accessories required are as traditional as in the normal scale factory just the difference in size, mass and in accuracy. Microfactory needs extremely precise machining, gripping, and handling units with user friendly interfaces. The following ball diagram shows the components of microfactory (figure 1).

Figure 1. The components of microfactory

At the present manufacturing system even if the final products are small, manipulators and other structural elements have high rigidity to suppress deformation under dead weight or by processing reaction force so the manufacturing system is significantly larger in relation to the products, [2].

2. MANIPULATOR KINEMATICS

It has been developed a 3 DOF RRR manipulator. The manipulator is very useful in our microfactory. It takes the parts from transfer line and positioning the parts in machining station 1 and 2. Also the manipulator is use in assembly station for realize actually assembly and to increase the precision of assembly. More precisely can be seen in figure 2.

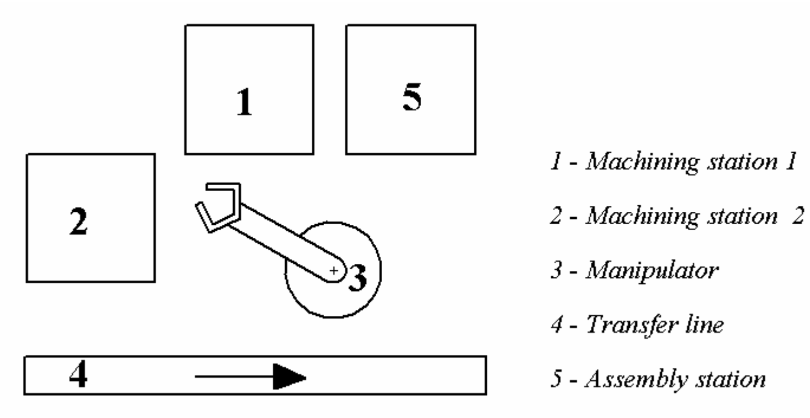


Figure 2. Importance of manipulator in the microfactory

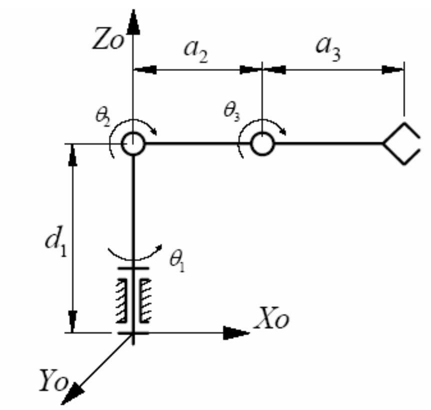


Figure 3. Manipulator kinematic diagram

For direct kinematics it was used the Denavit-Hanterberg method and the transformation matrix is given in equation 1, [4]:

$$A_{i,i-1} = \begin{pmatrix} \cos(\theta_i) & -\sin(\theta_i)\cdot\cos(\alpha_i) & \sin(\theta_i)\cdot\sin(\alpha_i) & a_i\cdot\cos(\theta_i) \\ \sin(\theta_i) & \cos(\theta_i)\cdot\cos(\alpha_i) & -\cos(\theta_i)\cdot\sin(\alpha_i) & a_i\cdot\sin(\theta_i) \\ 0 & \sin(\alpha_i) & \cos(\alpha_i) & d_i \\ 0 & 0 & 0 & 1 \end{pmatrix} \quad (1)$$

Based on relation (1) and figure 3, for our manipulator the transformation matrix from systems 0 to 3 are:

$$A_{1,0} = \begin{pmatrix} \cos(\theta_1) & 0 & -\sin(\theta_1) & 0 \\ \sin(\theta_1) & 0 & \cos(\theta_1) & 0 \\ 0 & -1 & 0 & d_1 \\ 0 & 0 & 0 & 1 \end{pmatrix} (2), \qquad A_{2,1} = \begin{pmatrix} \cos(\theta_2) & -\sin(\theta_2) & 0 & a_2\cos(\theta_2) \\ \sin(\theta_2) & \cos(\theta_2) & 0 & a_2\sin(\theta_2) \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} (3)$$

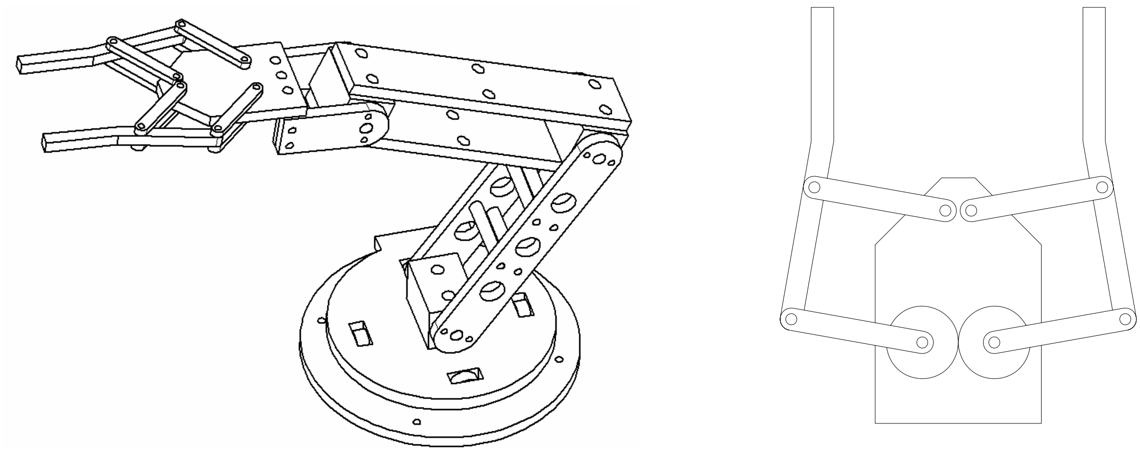
$$A_{3,2} = \begin{pmatrix} \cos(\theta_3) & 0 & -\sin(\theta_3) & a_3\cos(\theta_3) \\ \sin(\theta_3) & 0 & \cos(\theta_3) & a_3\sin(\theta_3) \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \quad (4)$$

The final transformation matrix is: $T_{3,1} = A_{1,0}\cdot A_{2,1}\cdot A_{3,2}$ (5)

The final transformation matrix will be this form: $T_{i,j} = \begin{pmatrix} R_{i,j} & D_{i,j} \\ 0 & 1 \end{pmatrix}$ where $R_{i,j}$ is the orientation matrix and $D_{i,j}$ is the origin coordinates matrix. There for, it is determined the manipulator position and orientation.

3. MECHANICAL DESIGN OF THE MANIPULATOR

The manipulator was designed in Solidworks CAD software. Solidworks is a complete 3D product design solution, providing the product design team with all the mechanical design, verification, motion simulation, data management, and communication tools that they need in one package. Our design is presented in figure 4.



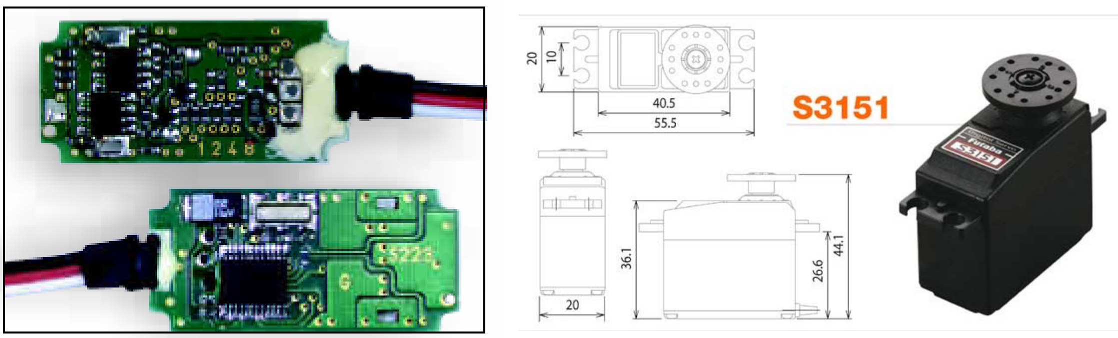
a) *b)*

Figure 4. a) 3D design of the manipulator, b) the mechanism of the gripper

All the elements are made by plastic and were manufactured using CNC machine Isel CPM 2018. The elements are assembled with the M3 screws and for the gripper it was used two gears to drive the mechanism. Work space is cylindrical with radius about 200 mm and the height is about 150 mm.

4. MANIPULATOR ACTUATION

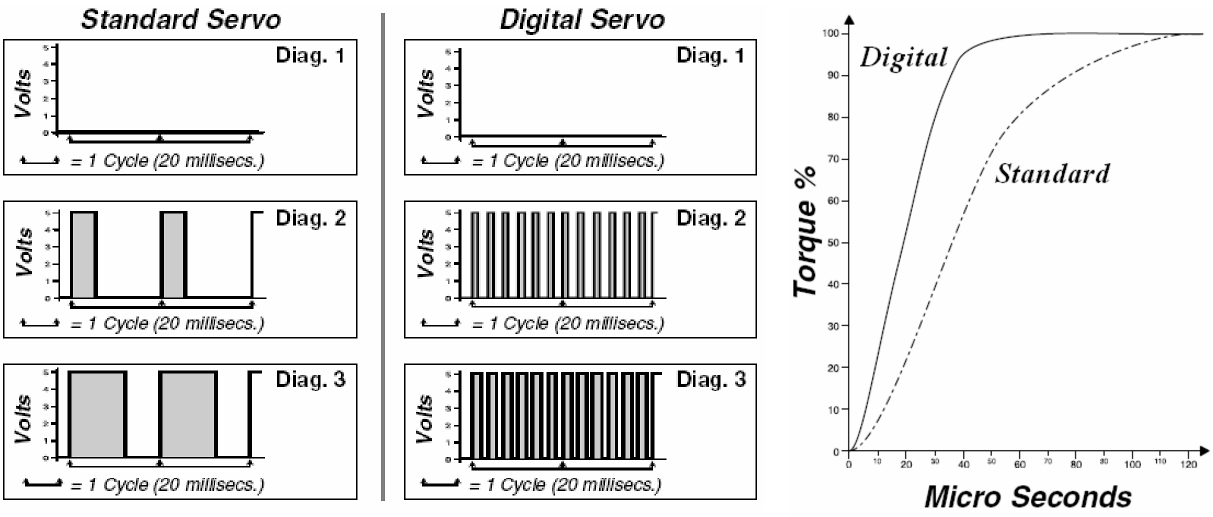
To actuate the manipulator it was used a motor from Futaba, model S3151. Over the last few years, servos have changed tremendously with size, rotational speeds and torque ever improving. To start with, a ‘digital servo’ is the same as a standard servo, except for a microprocessor, which analyses the incoming receiver signals and controls the motor. It is incorrect to believe that digital servos differ drastically in physical design to standard ones. Digital servos have the same motors, gears and cases as standard servos and they also, most importantly, have a feedback potentiometer just like their standard counterparts. Where a digital servo differs, is in the way it processes the incoming receiver information, and in turn controls the initial power to the servomotor, reducing the deadband, increasing the resolution and generating tremendous holding power.



a) *b)*

Figure 5. a) View of layout from motor Futaba S3151, b) Characteristics of motor S3151

In a conventional servo at idle, no power is being sent to the servomotor. When a signal is then received for the servo to move, or pressure is applied to the output arm, the servo responds by sending power/voltage to the servomotor. This power, which is in fact the maximum voltage, is pulsed or switched On/Off at a fixed rate of 50 cycles per second, creating small 'blips' of power. By increasing the length of each pulse/blip of power, a speed controller effect is created, until full power/voltage is applied to the motor, accelerating the servo arm towards its new position, [5].
The diagrams presented in figure 6.a show two cycles of 'on/off' power pulses/blips. Diag.1 - is idle. Diag.2 - has a short time/pulse i.e. a low power command to the motor. Diag.3 - is a longer pulse, power 'on' for longer, more power. A quick blip of power 'On', followed by a pause, does not give the motor much incentive to turn, whereas leaving the power 'On' for a longer period of time does. This means that a small control movement, which in turn sends small initial pulses to the motor, is very ineffective, and that is why there is what is termed a 'deadband'. In figure 6.b is related the comparison between digital and standard servos. This is a comparison graph showing the deadband between two Futaba servos with the same specifications.



a) *b)*

Figure 6. a) Diagram of signal for command the motor Futaba S3151, b) Comparison between digital and standard servos

5. FUTURE WORK AND CONCLUSION

It has been developed a manipulator which is very useful in our microfactory. It has been fixed the kinematics of manipulator and developed the mechanical structure, designing the manipulator using Solidworks. The actuation problem it was studied and an actuation system was developed based on Futaba servo motors. In the future we will propose a new gripping system that contains a compliant minigrippers, in order to grow the prehension precision.

6. REFERENCES

[1] Yuichi Okazaki; Nozomu Mishima; Kiwamu Ashida, "Microfactory –Concept, History and Development", Journal of Manufacturing Science and Engineering.
[2] Third International Workshop on Microfactories, http://www.ri.cmu.edu/events/iwmf02/, Date: 12.10.05
[3] Mohammad Aminul Islam, "Report on microfactory", Technical University of Denmark, Department of Manufacturing Engineering and Management
[4] Viorel Handra-Luca, Vistrian Mătieş, Cornel Brişan, "Roboţi, structură cinematică şi caracteristici", Printing House Dacia, 1996, Cluj-Napoca.
[5] http://www.futaba-rc.com/servos/digitalservos.pdf
[6] http://www.freescale.com/webapp/sps/site/application.jsp?nodeId=02nQXG7Kbj