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The Intelligent Modeling of Human Hand Motion Using Magnetic Based Techniques

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ABSTRACT
With increasing use of robots instead of human in industrial, medicine and military applications etc. the importance of research on designing and building of robots is increasing. In this paper various methods of the human hand motion simulation has been investigated and we used one of most common method named Data-gloves which extract data from hand and then we simulated hand motion during several processing stages. At first step we designed and built circuits to digitize analog data received from sensors and we sent them to computer. Then we received extracted data in MATLAB and processed them to simulate bending of the wrist and fingers joints graphically. In this method we mapped data linearly to 0-90 and rotate points around relative Coordinate axis in the specific conditions. Results show that we can simulate hand motion in real time with low cost, lowest error and without complex and expensive equipments.

KEYWORDS: Hand motion simulation, Data-Glove, Data extraction circuit, simulation in MATLAB.

1. INTRODUCTION

Nowadays using robots to replace human resources is widely used. Sometimes the robots are pre-programmed to perform specific and common tasks. But in some conditions such as critical tasks, unpredictable environment and complex situations the human role and his so fast dissension making cannot be completely eliminated and his direct and continuous control is necessary. Then we need some kind of robots that imitate human motion. Considering the importance of simulation, so many ways is presented to simulate human motion. The main difference in the simulation models is due to differences in methods of data extraction. Different data extraction techniques can be grouped into three general approaches: Data extraction by data gloves - Data extraction by image processing - Data extraction from electromyogram signals. Here we describe these methods more detailed.

2. VARIETY OF DATA EXTRACTIO METHODS FOR HAND SIMULATION

2.1. Data extraction by Data-Glove

Data-Glove is made of many sensors to digitize hand motion and provides more natural relationship between man and robot [1]. In comparison with other input devices such as keyboard, mouse and joystick it provides more detailed and complex information. Data-Gloves are known with commercial brands such Sayre Glove, MIT LED Glove, Digital Data-Entry Glove, Data-Glove, Dexterous Hand-Master, Power Glove, Cyber Glove, VPL Glove and Space Glove [2]. There are different types of Data-gloves and in this paper we point out to some of most important types of them. One of the most common type of Data-gloves are the gloves that use variable resistance to bending (strain gauge). Tekscan[3] company has made a combination of strain gauge sensors with linear output to detect amount of the fingers bends. Thus using neural networks and other methods for linearization of nonlinear data is not needed.

In other types of Data-Gloves the infrared transmitter receiver sensors are used to detect bending of the fingers (Fig.2) [1]. In these sensors transmitter is connected to receiver through a pipe which is route of the infrared waves. These sensors are placed in the joints of the Data-glove fingers and with bending of the joints pipe bends. Infrared transmission path are changed and therefore it will cause decreasing received infrared waves in receiver.

These data are non-linear so in several calibration steps and using neural networks they are converted to linear data. In other types of Data-Gloves the sensors composed of orthogonal coils are used [4]. In this method one of the coils as a transmitter is located on the hand and six of them are used as receiver are located on the fingertips and wrist (Fig. 3). Against previous methods, instead of measuring bending of the joints, hand motion detection is done with finding of position of fingertips.

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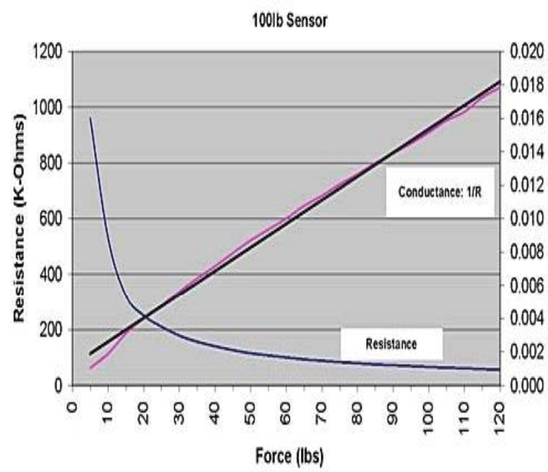

Fig. 1. Strain gauge sensors with linear output

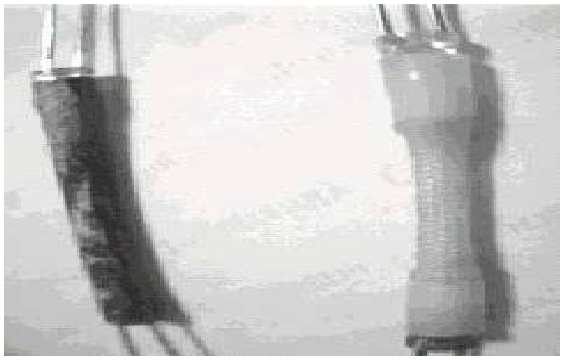

Fig. 2. The finger-bend sensors with two flexible pipes of different materials [1].

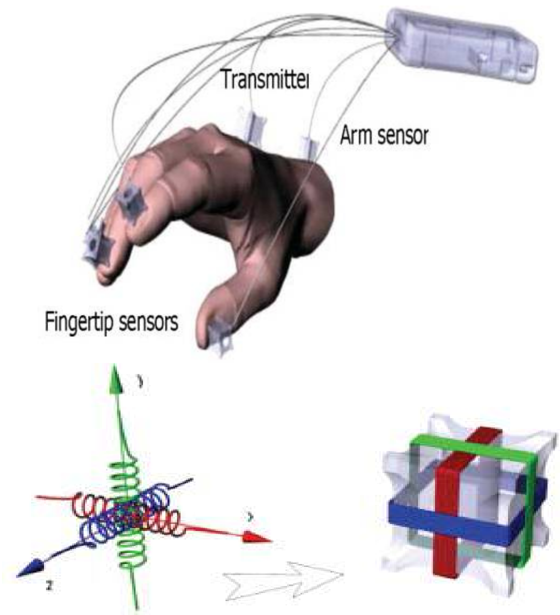

Fig. 3. Coils placement on the hand and Orthogonal coils antenna for transmitter/receiver [4].

Against previous methods, instead of measuring bending of the joints, hand motion detection is done with finding of position of fingertips. In this method processing unit provides electromagnetic waves in environment by transmitter sensor that cases magnetic induction in receiver sensors. Processing unit with measuring this induction in receiver sensors and processing them, can identify position and rotation of the fingertips.

2.2. Data extraction by image processing

In this method, by using a camera, various parameters of hand are investigated. In this model based on the various factors hand motion is detected. A method for detecting motions is based on the reorganization of the edges [5]. In this method a classifier named Haar is trained during a relatively long time. This classifier classifies the extracted data and using Adaboost algorithm in Matlab during five image processing stages, image edges are detected and virtual hand is controlled (Fig. 4).

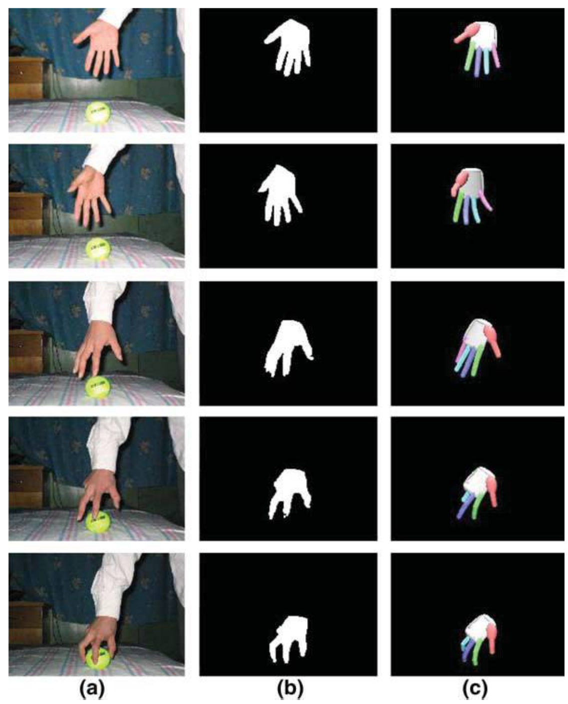

Fig. 4. (a) Original images, (b) segmented images, (c) tracking Result [7]

2.3. Data extraction by electromyogram signals

In this method the nerve signals of brain is used to control the robot [8][9][10][11][12][13]. As shown in Fig.6 (a) and Fig.6 (b), in this method electromyogram signals sent by the brain is received by sensors. Received signals were processed and various characteristics such as frequency, power, energy, Fourier series coefficients or a combination of them, etc. for identifying the type, pressure and direction of motion is extracted from marrow. Then the extracted information is classified and will be sent to the controller for controlling an artificial organ. Finally by the user visual feedback can be mor carefully controlled artificial organs. Above steps briefly is shown in Fig.7.

Fig. 5. Marker-settings for hand movements [6]

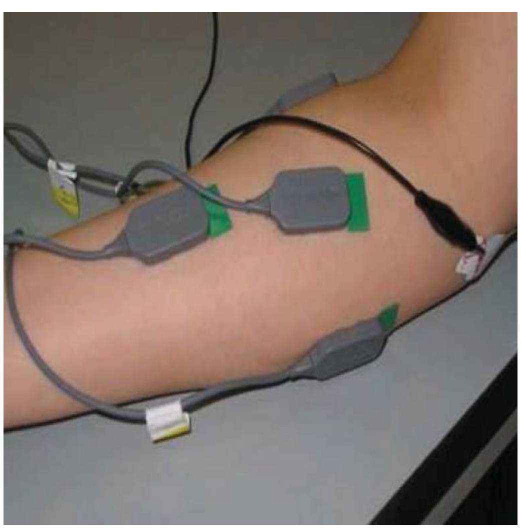

Fig. 6(a). Surface EMG sensors

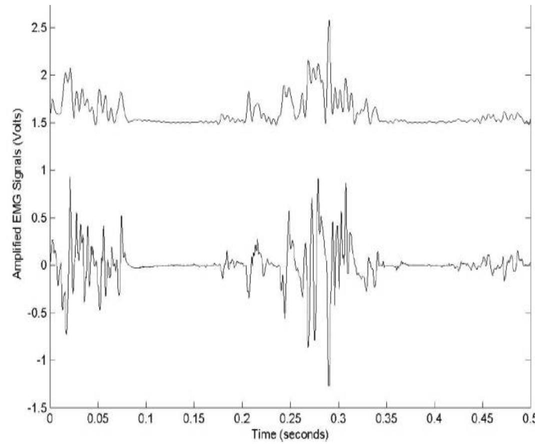

Fig. 6(b). Revised EMG signals

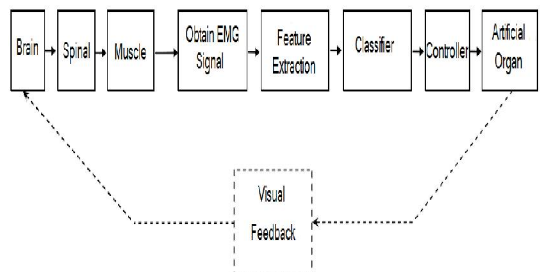

Fig.7. Block diagram of the cybernetic hand control mechanism [12]

3. PRESENTED SIMULATION

3.1. Data extraction and sending to computer

Simulation performed by us is based on Data-gloves using sensors varies with the bending (strain gauge) with a linear output and large resistance range. In this paper, we measured and simulated the bending of the 7 joints of hand. Therefore 7 sensors are embedded in the specified locations. The strain gauge sensor output voltage is very small therefore; by the circuit shown in fig.8 we mapped output voltage range of strain gauge sensors to the range of 0-5 volts. In this circuit R2=R12=10K ,Vx=4.21 , R2/R11=1.25 and R1 =24k [14]. As shown in fig.8, sensors No. 1, 2, 3 and 4 are measuring the bending of the index, middle and ring fingers around the x axis and No. 7 sensor measuring the bending of the wrist around the x axis and No. 5,6 sensors are measuring the bending of the Thumb around the y and z axis. Then the analog extracted data is converted to digital data by the Atmega32 microcontroller that sampling rate is selected to be 172.688 KHz. In next step digital data must be sent to the computer. Therefore they are placed in UDR register and the start, parity and stop bits are added to them and data is send from Atmega32 as asynchronous in 9600 bond rates. In order to send data can be used in the computer we use the MAX232chip and its output is sent to COM port of the computer by RS232 interface. Related circuit to the extraction, digitization, sending and conversion to computer-usable data for one sensor is shown in Fig.9.

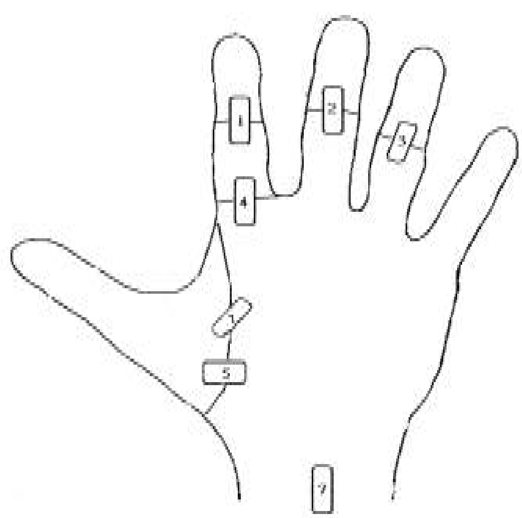

Fig.8. Positions of the sensors on the data glove [1].

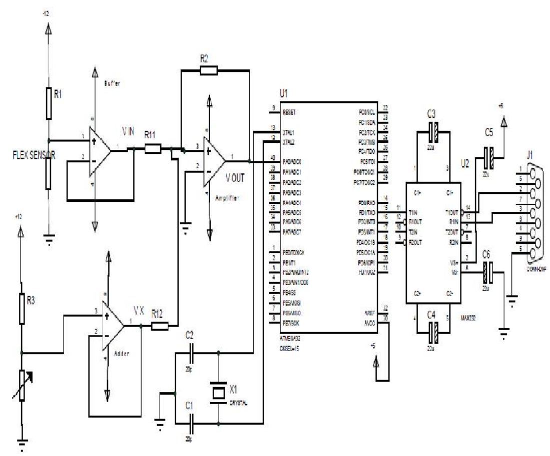

Fig.9. Circuit of the extraction [14], digitization, sending and conversion to computer-usable data for one sensor

3.2. Receiving data in MATLAB

At this stage we will receive data sent from the circuit in MATLAB [15][16][17]. And with processing the data a virtual hand is controlled according to the received data. As mentioned digital data from seven sensors installed on the Data-glove will be sent to the computer and these data are stored in a 1*7 matrix. Members of this matrix are the numbers in the range of 0-5 volts [14]. Since the bending angle of the virtual hand joints should be in the range 0-90 degrees thus, we linearly map the received data to 0-90.

3.3. Rotation one point around another point

For rotation the P point with coordinates [x (2) y (2) z (2) 1] around the axis of coordinates x, y or z to size θ, coordinates of P point must be multiplied respectively to the matrix of Rx, Ry or Rz. For example, rotation around x axis is as follows:

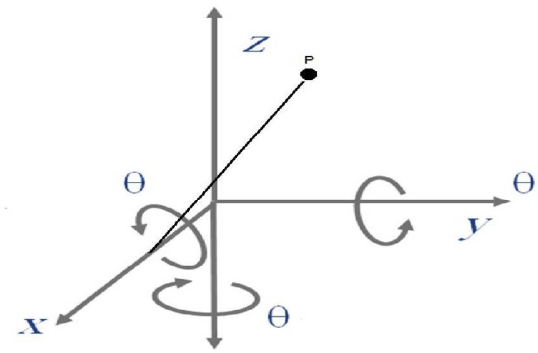

Fig.10.P point rotation around x axis

$$R_x=\begin{bmatrix}1 & 0 & 0 & 0\\ 0 & \cos & -\sin & 0\\ 0 & \sin & \cos & 0\\ 0 & 0 & 0 & 1\end{bmatrix}$$

$$R_y=\begin{bmatrix}\cos & 0 & \sin & 0\\ 0 & 1 & 0 & 0\\ -\sin & 0 & \cos & 0\\ 0 & 0 & 0 & 1\end{bmatrix}$$

$$R_z=\begin{bmatrix}\cos & -\sin & 0 & 0\\ \sin & \cos & 0 & 0\\ 0 & 0 & 1 & 0\\ 0 & 0 & 0 & 1\end{bmatrix}$$

$$[\mathrm{Xnew}(2) \quad \mathrm{Ynew}(2) \quad \mathrm{Znew}(2) \quad 1] = [\mathrm{X}(2) \quad \mathrm{Y}(2) \quad \mathrm{Z}(2) \quad 1] * \mathrm{Rx}$$

But for rotation P point around transmitted x axis to O = [x (1) y (1) z (1) 1] point, we perform as follows:

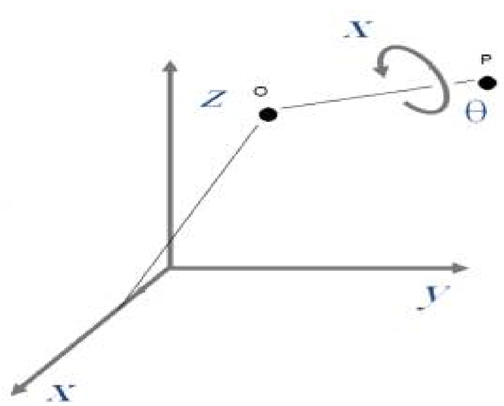

Fig.11.rotation *P* point around transmitted x axis to O point

$$M=\begin{bmatrix}1 & 0 & 0 & -\mathrm{X}(1)\\ 0 & 1 & 0 & -\mathrm{Y}(1)\\ 0 & 0 & 1 & -\mathrm{Z}(1)\\ 0 & 0 & 0 & 1\end{bmatrix}$$

$$[\mathrm{Xnew}(2) \quad \mathrm{Ynew}(2) \quad \mathrm{Znew}(2) \quad 1] = (\mathrm{Inv}(\mathrm{M})) * \mathrm{Rx} * \mathrm{M} * [\mathrm{X}(2) \quad \mathrm{Y}(2) \quad \mathrm{Z}(2) \quad 1]'$$

First, to hand graphical simulation we define the points and to build base state for four fingers virtual hand we connect the points to each other as shown in fig.12. Bending angle of the Joints in the Ground state is 0 degree.

Considering the relations mentioned in rotation one point around another point, the manner and amount of the bending of the joints in the simulation can be described as follows: point No.1 rotation around point No.2 along the x axis indicates joints bending in point No.2 and Rotation Point.

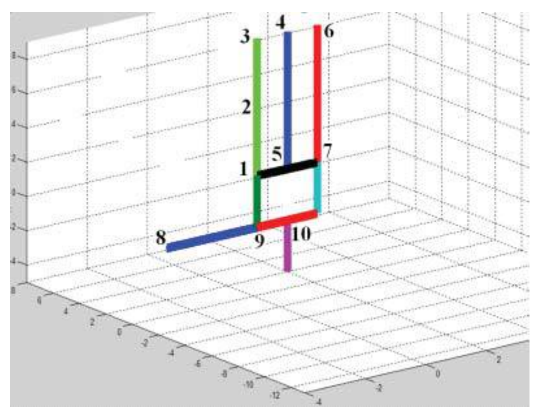

Fig.12. Virtual hand in base position

No. 1 and 2 around point No.3 indicate joints bending in point No.3. Thus, with mapping values from sensors to the angles and assigning these angles to amount of point's rotation, the joints bending of the visual hand is controlled. It is obvious when a point is rotated, also dependent points to rotated point must be rotated. Otherwise length of rotated finger will change and the simulation will be incorrect. For example, when the virtual hand is bent at point No.10 all other points must also be rotated around the point No.10. Summarizes of all needed steps to simulation are shown in fig 13. Some states of the simulated virtual hand are shown in fig.14.

4. CONCLUSIONS

In this paper, using sensors variable with bending, bending of the user's fingers measured. After digitization of analog extracted data and sending them to the computer, in MATLAB they were mapped to the range 0-90 degrees. Then by the related relations in rotation one point around another point we simulated and controlled the motion of the virtual hand. According to the results observed that virtual hand quickly, smoothly and carefully repeats hand motion of the user. In the future we will simulate hand motion in all degrees of freedom by our method and also using electromyogram waves and we will extend it to simulate all movement parts of body.

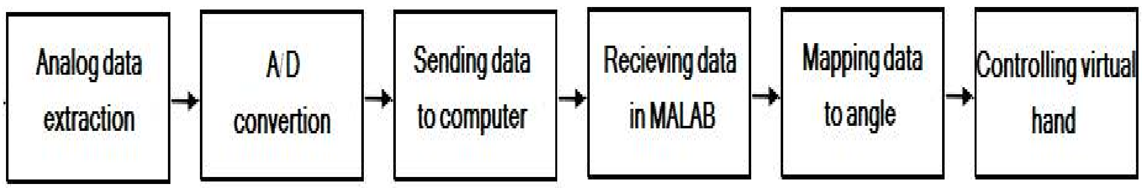

Fig. 13. All needed steps to simulation

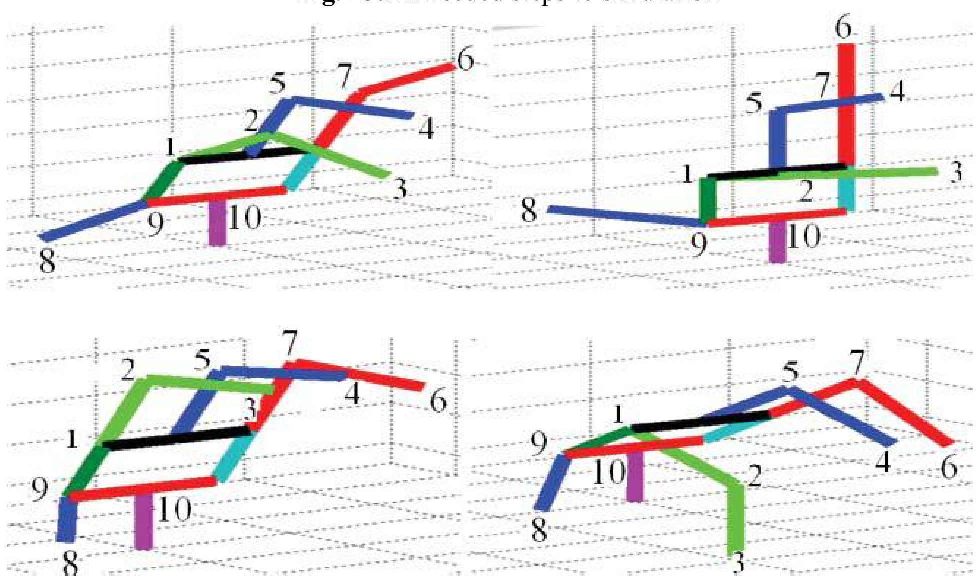

Fig.14. Some states of the simulated virtual hand

REFERENCES

[1] Chin-Shyurng Fahn and Herman Sun, "Development of a Sensory Data Glove, "Using Neural-Network-Based Calibration", Taipei, Taiwan: ICAT 2000, pages 1-8.

[2] Sturman, D.J.; Zeltzer, D. "A survey of glove-based input", IEEE Comput. Graphics, 14, 30-39, 1994, pages 106-111.

[3] [Online], Available: www.tekscan.com/flexiforce

[4] M. Bezdicek1, D. G. aldwell2"PORTABLE ABSOLUTE

POSITION TRACKING SYSTEM FOR HUMAN HAND FINGERTIPS", Proceedings of Virtual Concept 2006, pages 67-75.

[5] Catalin Constantin Moldovan and Ionel Staretu Sinaia, Romania ,"Real-time gesture recognition for controlling a virtual hand", ISBN 978-1-84626-xxx-x,Proceedings of 2011 International Conference on Optimization of the Robots and Manipulators (OPTIROB 2011)Sinaia, Romania, 2011,pages 216-220.

[6] J.Kang, B.Badi, Y. Zhao and D. K. Wright, "Human Motion Modeling and Simulation by Anatomical Approach", WSEAS Transactions on Computers 5(6): 1325-1332, Apr 2006pages 50-58.

[7] Jinshi Cui, Zengqi Sun "Model-based visual hand posture tracking for guiding a dexterous robotic hand", ELSEVIER, Pages 311–318, May 2004, pages 201-207.

[8] www.kya.ir.

[9] Sebastian Bitzer, Patrick van der Smagt, "Learning EMG control of a robotic hand: Towards Active Prostheses", IEEE International Conference on Robotics and Automation, Orlando, Florida - May 2006, pages67-72.

[10] Kai J. Miller, Beau Crawford, and Rajesh P. N. Rao "Online Electromyographic Control of a Robotic Prosthesis" IEEE TRANSACTIONS ON BIOMEDICAL ENGINEERING, VOL. 55, NO. 3, MARCH 2008, pages 14-21.

[11] Takamitsu Matsubara, Sang-Ho Hyon and Jun Morimoto, "Learning and Adaptation of a Stylistic Myoelectric Interface: EMG-based Robotic Control with Individual User Differences", Brain Machine Interface Development, 2011, pages 251-259.

[12] Mehran Eftekhari, "Hand Motion Route Detection by Surface EMG Signal and Marcof Hidden Model" A thesis presented to Sharif University of Technology, Tehran 2005, pages 79-84.

[13] Amir Hossein Omidvar, "EMG Feature Extraction to Control the Prosthetic Hand "A thesis Presented to Sharif University of Technology, International Campus, Kish Island, Iran, 2010pages 151-158.

[14] Kostas N. Tarchanidis, Member, IEEE, and John N. Lygouras , "Data Glove With a Force Sensor "IEEE TRANSACTIONS ON INSTRUMENTATION AND MEASUREMEN", VOL. 52, NO. 3, JUNE 2003, pages 88-95.

[15] http://www.edaboard.com/thread47834.html .

[16] www.mathworks.com/help/toolbox/instrument/serialreceive.html.

[17] http://www.mathkb.com.