Annals of DAAAM for 2010 & Proceedings of the 21st International DAAAM Symposium, Volume 21, No. 1, ISSN 1726-9679
ISBN 978-3-901509-73-5, Editor B. Katalinic, Published by DAAAM International, Vienna, Austria, EU, 2010
Make Harmony Between Technology and Nature, and Your Mind will Fly Free as a Bird
DAAAM Symposium

DESIGN OF A TRAINING AND REHABILITATION UPPER LIMB ORTHESIS WITH ACTUATORS

GRECU, V[alentin] & GRECU, L[uminita]

Abstract: *This paper presents a design of an upper limb orthesis for rehabilitation and training. The orthesis is controlled with 3 DC motors. The three motors are driven by an accelerometer. For each joint (wrist and elbow), the laws of motion associated with flexion-extension and pronation-supination movements were obtained using a Maple application based on experimental data acquired with SIMI-Motion. They were used to control the movements of the simplified model. The torqueses of the motors were deduced using the reacting forces which appear in the joinst associated with the considered movements.*

Key words*: rehabilitation robotics, human upper limb, orthesis forearm, dynamic human arm*

1. INTRODUCTION

The rehabilitation human upper limb is as important as it is difficult. A real support in this effort is the use of orthosis. Their adaptation is hard to be done because it is difficult to determine with precision the spatial position as well as the forces needed for the replacement of the muscle. The upper limb orthesis function is to simulate its biological equivalents. It is necessary to study the properties of the biological materials that make up the human body, and also the measures involved in the differential equations must be as correct as possible.
The kinematic chain proposed is presented in figure 1.

The design of the orthesis is based on the reacting forces which appear in elbow joint associate with pronation-supination movements (point D),wrist joint associate with flexion-extension (point G) and deviation ulnar-radial (point F) movements (Panjabi & White, 2001).

The human upper arm model is composed by the following segments (Netter F.H, 1990): shoulder, arm, forearm, hand and joints (shoulder, elbow and wrist).

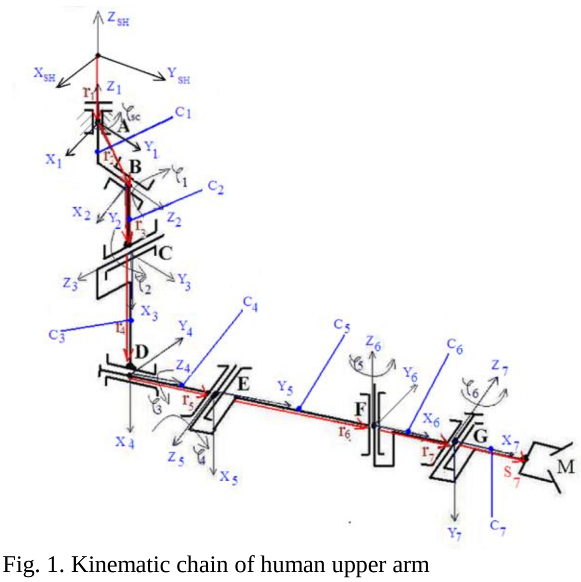

Fig. 1. Kinematic chain of human upper arm

2. LAWS OF MOTION FOR THE FOREARM

In order to determine the reacting forces which appear in the elbow joint, and also to command and to control the orthesis, the laws of motion were obtained.

Considering the usual movements of the forearm a lot of experimental data were collected using SIMI-Motion software.

Using a Maple application, based on the method of least squares we obtained different graphics and approximation models.

For example, for pronation-supination movement (elbow joint) - characterized by phi4 angle we get the following:

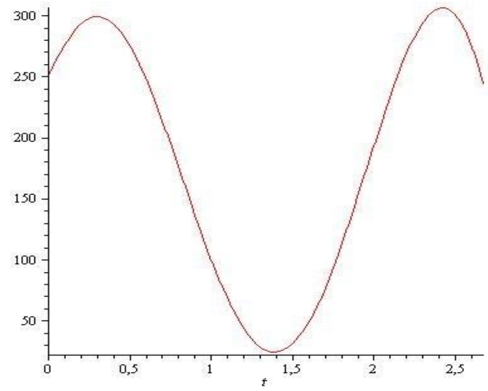

Fig. 2 Law of motion for pronation-supination

The approximation model for phi4 angle [degree] is:

$$\text{phi4} := 251.1694102 + 280.1911032 * t - 174.0441791 * t^2 - 1070.749959 * t^3 + 1180.331042 * t^4 - 414.7173299 * t^5 + 47.35080004 * t^6.$$

For flexion-extension movement (wrist joint)-characterized by phi6 angle we get the following:

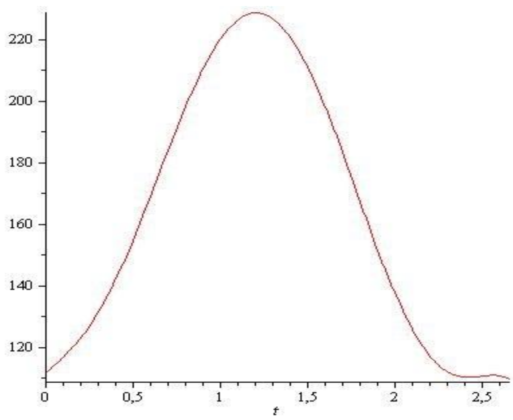

Fig. 3. Law of motion for flexion-extension movement

The approximation model for phi6 angle [degree] is:

$$phi6 := 111.8713681 + 51.76294823 * t - 49.14789084 * t^2 + 454.4603127 * t^3 - 535.2214505 * t^4 + 215.7291701 * t^5 - 29.01829866 * t^6.$$

In paper (Grecu et al., 2010), the reacting forces which appear in the elbow joint associated with flexion-extension and pronation-supination were deduced using the Newton Euler formalism and again with Maple programs (Zeid I., 1991).

The differential equations of the motions are:

$$\delta q^T \cdot \left[M \cdot q - Q^a \right] = 0 \qquad (1)$$

where M is matrix of masses, q is generalized coordinates vector, Q^a is matrix of generalized active forces

As a result of integrating for $t \in [0;3.0]$ and the initial conditions we have obtained (see Grecu et al., 2010), the following graphic representations of the reacting forces

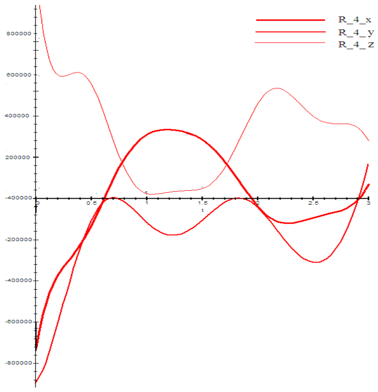

Fig. 4 Graphic diagram of reacting forces for pronation-supination movement, $t \in [0;3,0]$

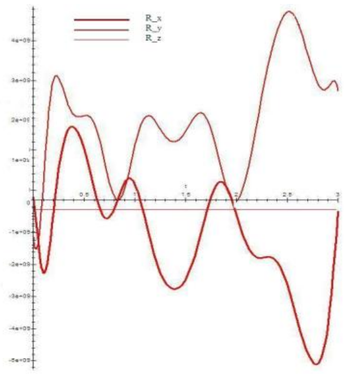

Fig. 5. Graphic diagram of reacting forces for flexion-extension movement, $t \in [0;3.0]$

3. COMMAND AND CONTROL OF THE FOREAM ORTHESIS

Proposed orthesis is driven by three DC servomotors for each of the three joints of the forearm (pronation-supination the elbow joint, flexion-extension movement and ulnar-radial deviation of wrist joint). Command and control of the orthesis is made with a remote control which included in it an accelerometer. The orthesis can be mounted on a patient's forearm and executes movements accurately reproduced by the hand physiotherapist (Kiguchi et al., 2008).

To achieve this a computer code was developed in Arduino software. Signals received from the accelerometer is transmitted immediately to orthesis actuators (servomotor Hitec HS-645MG). The accelerometer is model MMA7260QT MEMS (micro-electro-mechanical systems) three axis, a great low-g sensor with adjustable sensitivity from ±1.5 g to ±6 g. The orthesis is further mounted on the forearm of the patient.

The simplified model of the orthesis can be programmed through the interface unit (Figure 6).

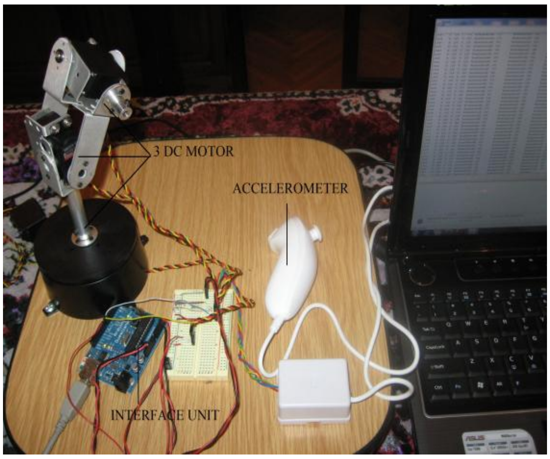

Fig. 6. Upper limb orthesis scheduled

Orthosis motions controlled by the accelerometer follow the laws of motion of the forearm (elbow and wrist joints). These laws were experimentally determined using images captured by video analysis system SIMI-Motion.

In this experiment were determined laws of motion of the forearm, performing several movements of human upper limb including the current daily activities in which hand is used.

4. CONCLUSION

We have proposed to design a upper limb orthesis based on the determinate the reacting forces which appear in elbow and wrist joint. The model presented in the paper can be extended to be used with other dates experimental obtained for certain usual activities proper to the upper limb and for larger periods of time.

A further goal of our work is to test this orthesis through computer simulation in order to demonstrate its validity.

In order to validate the forearm orthesis the laws of motion of elbow and wrist joint of the patient need to be compared with the laws of motion determined experimentally with SIMI Motion for a healthy subject.

5. REFERENCES

Netter F.H.," Atlas of Human Anatomy", Second Edition, Novartis, New Jersey, 1990

Zeid I., CAD/CAM Theory and Practice, McGraw-Hill, 1991

*** - Maple 12 User Guide, MapleSoft, Inc.

Dragulescu D., Dynamics of Robots, Editura Didactica si Pedagogica Bucuresti, 1997

Abrahams P.H., Hutchins R.T., Marks S.C. Jr., McMinns "Colour Atlas of Human Anatomy", Mosby, London, 4-th ed., 1998

Papilian V., "Anatomia omului", vol. I – Aparatul locomotor, Editura ALL, Bucuresti, 1998

Panjabi M., White III, A. "Biomechanics in the musculoskeletal system", Churchill Livingstone , New York, 2001

Ranathunga Arachchilage Ruwan Chandra Gopura, Kazuo Kiguchi "EMG-Based Control of an Exoskeleton Robot for Human Forearm and Wrist Motion Assist", IEEE International Conference on Robotics and Automation Pasadena, USA,pg 731-736, 2008

Grecu V., Dumitru N., Grecu L. "Modeling dynamic behavior of human upper limb kinematic chain", ICOME , 2010