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SOME CONSIDERATIONS REGARDING A ROBOTIC SYSTEM FOR HUMAN UPPER LIMB MOTIONS REHABILITATION

Valentin Grecu [1], Cristian Copilusi [1]
University of Craiova. Faculty of Mechanics
Vali.Grecu@cez.ro, cristache03@yahoo.co.uk

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Abstract. In this paper a human upper limb robotic system is analyzed through an experimental study. The experimental analysis aim is to validate this robotic system type in order to use it in some kinetotherapy programs for the human upper limb recovery. The robotic system experimental research was performed by using equipment called SIMI Motion which enables to evaluate angular variations in 2D environment. Through this equipment used we establish the angular variations developed at the robotic system joints level. This paper consists of three main parts. In the first part there is an actual study of the robotic systems specially designed for the human upper limb rehabilitation, and in second part, the robotic system proposed for this experimental research is described. In the third part the experimental research is described in detail.

1. INTRODUCTION

Many research centres have developed different types of robotic systems used in human upper limb functional recovery. As a first example, a group of researchers, lead by J. Rocon and J.L. Pons (Spain) have designed an exoskeleton called WOTAS which offers a solution to the patients who cannot take medication by themselves. The role of the WOTAS exoskeleton was to eliminate the human upper limb trembling when patients take medication. This robotic system has three degrees of freedom which correspond with the elbow flexion/extension, pronation/supination and wrist flexion/extension [10]. Another robotic system was designed by a group of researchers from Holland, lead by Schiele and Van der Helm, and the aim was to enable astronauts from International Space Station (ISS) to control a robot called EUROBOT (Schoonejans et al., 2004) at a distance, in space.

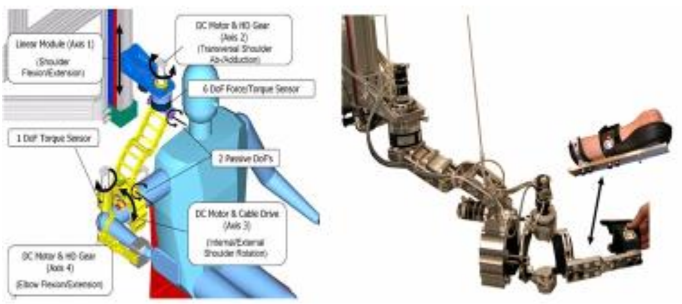

Figure 1. ARMin exoskeleton for human upper limb recovery

This was realized with an interface human-machine type which enables to control the feedback force level [13, 14]. For physiotherapy recovery programs an exoskeleton called ARMin II was elaborated (T. Nef, M. Mihelj, G. Colombo, R. Riener). This has 6 DOF and enables pronation/supination and flexion/extension motion at the wrist level [15]. The fingers are not obstructed by the exoskeleton forearm structure (figure 1). Other robotic systems which have as a main application the human upper limb therapeutically recovery programs are presented in [16, 17, 12].

2. THE ROBOTIC SYSTEM PROPOSED FOR MOTION ANALYSIS

In the University of Craiova - Faculty of Mechanics research frame, a group of researchers under the lead of PhD. Eng. Dumitru N., have developed a robotic system prototype used for human upper limb therapeutic programs implementation. This robotic system is presented in figure 2 and it consists of two main parts. The first part is made up of a proper exoskeleton, and the second part is represented by the command and control unit. The exoskeleton has 3 DOF, which ensures the wrist flexion/extension, abduction/adduction and forearm pronation/supination motions. These motions are enabled through 3 servo-motors. The exoskeleton model is designed by taking into account the models developed in [6, 7, 8].The exoskeleton elements are manufactured from aluminium alloy and the torques developed by the servo-motors are transmitted through two conic gears and one cylindrical gear to the exoskeleton elements. These gears are manufactured from plastic material through virtual prototyping procedures.

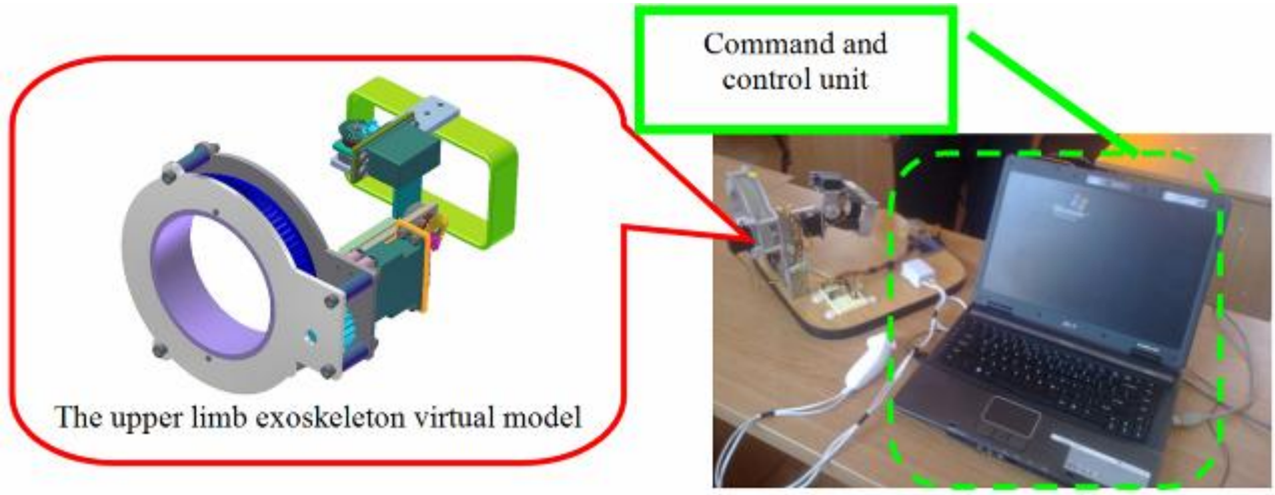

Figure 2. ARMin exoskeleton for human upper limb recovery

The command and control unit consists of a processing board Arduino DuemiLanove type, which ensures an interface between servo-motors and a notebook. At the same time, the power supply taken from the notebook for servo-motors is ensured through this board. A driver is installed on the notebook in order to control and command the servo-motors. This driver as an interface through a software which enables us to elaborate different command and control algorithms under C++ environment. These algorithms are elaborated by taking in account the human upper limb kinetotherapy protocols, in accordance with the motion laws developed by this at the wrist and elbow joints level from a healthy human subject. This robotic system was designed in such a manner that it can be controlled even through a joystick. It has an accelerometer integrated in its structure which enables the exoskeleton to perform spatial motions in accordance with the ones performed by the kineto-therapist.

3. ROBOTIC SYSTEM MOTION ANALYSIS BY USING SIMI MOTION EQUIPMENT

Taking into account the experimental research aim, the motions developed by the robotic system presented here will be evaluated experimentally by using motion analysis equipment, which is called SIMI Motion. It has one high speed camera for capturing and recording sequences and an ACER notebook for sequences analysis in real time with SIMI software [2]. The University of Craiova-Faculty of Educational Physics and Sport owns this special equipment, which is used for the experimental research presented in figure 3. This equipment enables us to determine the desired points trajectories, displacements, velocities, accelerations and planar angular variations biomechanical mobile systems through successive identifications of the joint centers positions in their structures. The general procedure for experimental determinations is shown in figure 5. Thus, one attached markers in the rotation joints centers with a view to determining the angular amplitude developed by the robotic system for the equivalent human forearm motions. In order to start this experimental research it is well known from the specialty literature, the angular amplitudes developed by a healthy human subject at the forearm and hand level [1, 5, 9, and 11]. These angular amplitudes are shown in Table 1.

Table 1.

Motion	Average (deg)	Angular amplitude
Wrist flexion/extension	850 – 0 - 75°	155°- 160°
Wrist abduction/adduction	200 – 0 – 35°	50°- 55°
Elbow pronation/supination	900 – 0 - 70°	150°- 160°
Elbow flexion	0- 1420	135°- 142°

Figure 3. SIMI Motion analysis equipment and the installing mode onto proposed robotic system

Figure 4. The human forearm used for the experimental studies, and trauma zones identification

A sequence of the experimental analysis using this equipment is shown in figures 6, 7, and 8 for the robotic system imposed motions such as: flexion/extension, abduction/adduction, pronation/supination. In these sequences the robotic system performs motions equivalent to ones developed by a human healthy forearm, and it uses a human subject who has a bony trauma at the wrist joint level (figure 4). The robotic system implemented motions take into consideration some kineto-therapy procedures, which were elaborated especially for this.

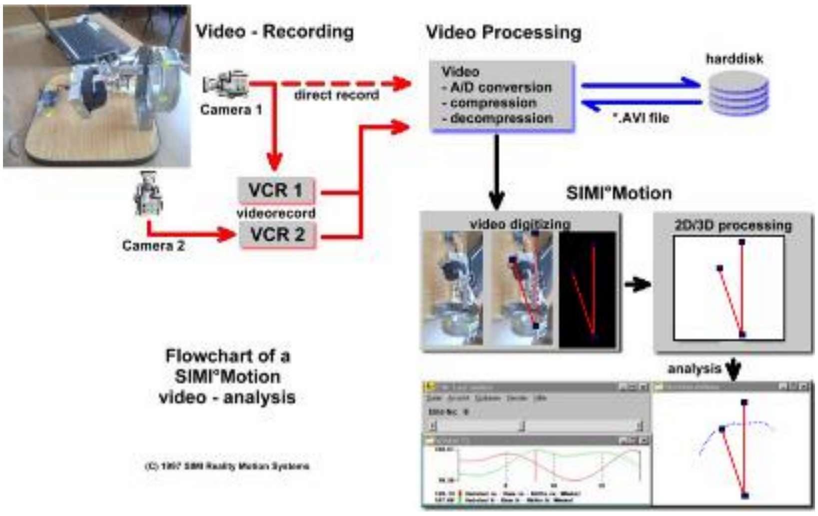

Figure 5. SIMI Motion Analysis scheme [2]

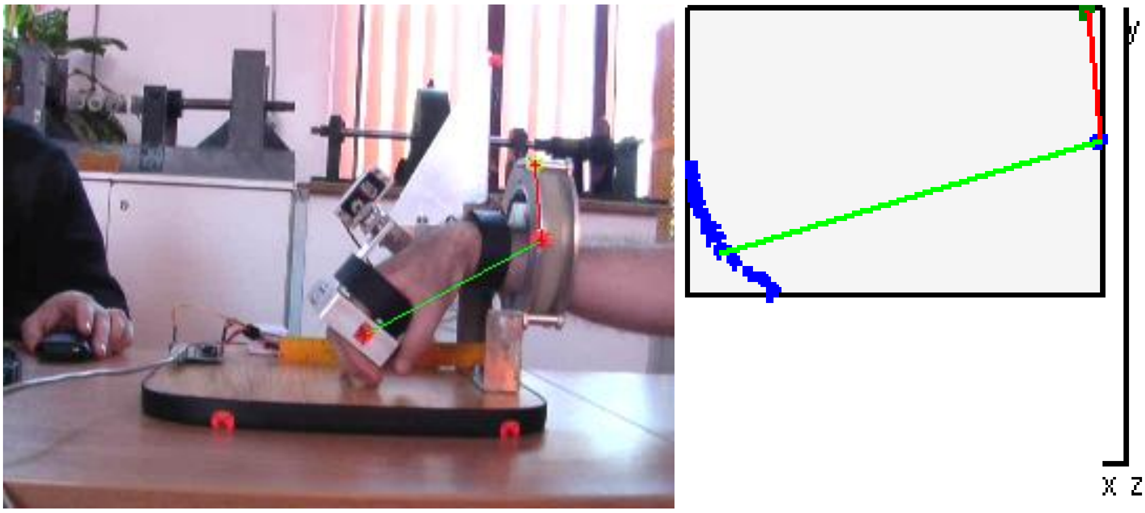

Figure 6. Flexion/extension motion analysis performed by the robotic system using SIMI Motion equipment

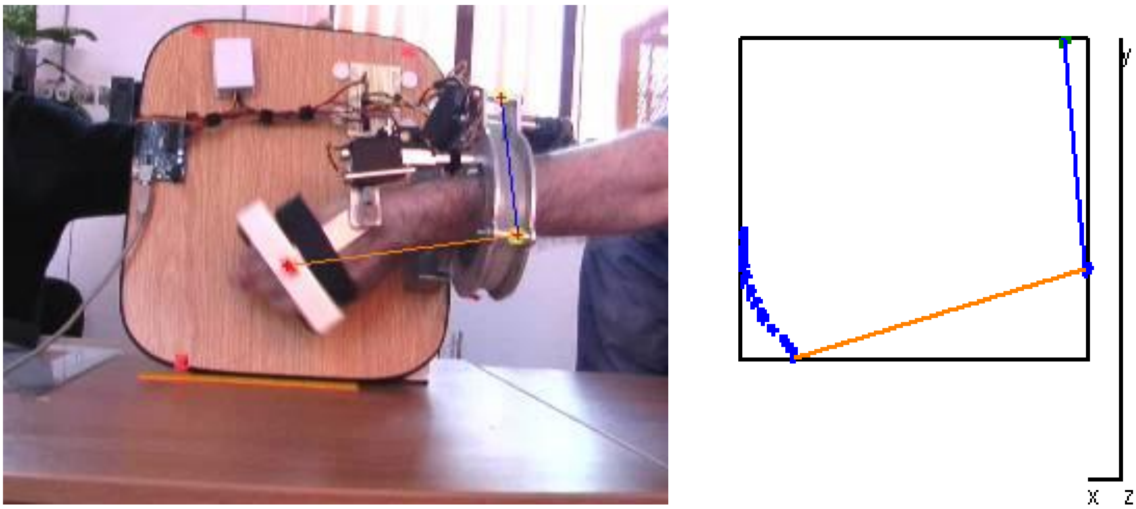

Figure 7. Abduction/adduction motion analysis performed by the robotic system using SIMI Motion equipment

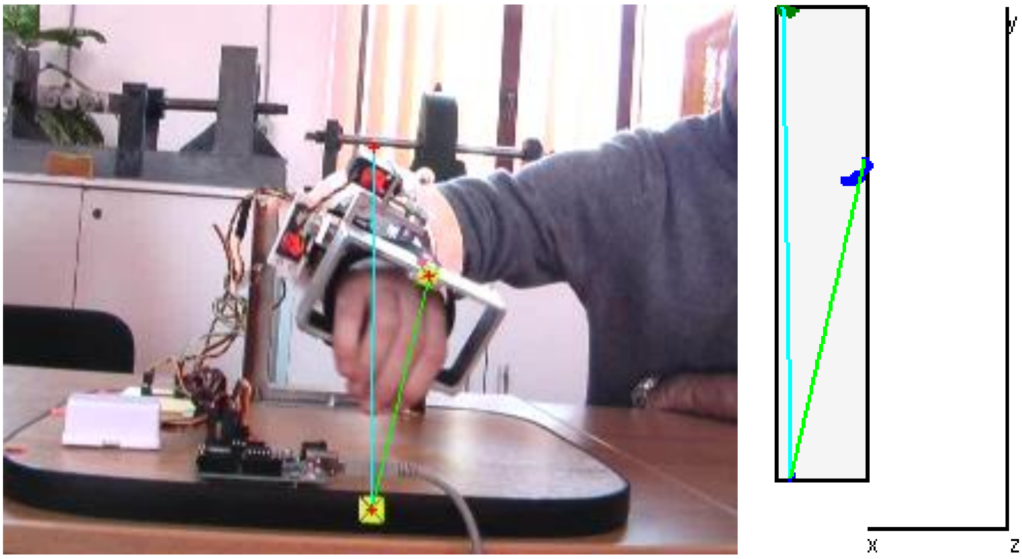

Figure 8. Pronation/supination motion analysis performed by the robotic system using SIMI Motion equipment

4. CONCLUSIONS

As a result of the experimental analysis, one obtained the motion laws developed by the robotic system for flexion/extension, adduction/abduction and pronation/supination motions equivalent to the ones developed by the human upper limb wrist. These are shown in figures 9,10 and 11. By analyzing the results shown in figures 9, 10, and 11, one can observe that the angular amplitudes developed by means of the robotic system are similar to the ones developed by the human forearm in a healthy human subject (these are specified in table 1). Thus, one can notice that the human wrist flexion/extension motion has angular amplitude equal to 156, 9 degrees, for which this value ranges from 155 to 160 degrees. For abduction/adduction motion, the angular amplitude is 51, 51 degrees and the value limit for this motion type is between 50 - 55 degrees. In the last case, for pronation/supination motion, the angular amplitude is 156, 1388 degrees and the value limit is between 150-160 degrees.

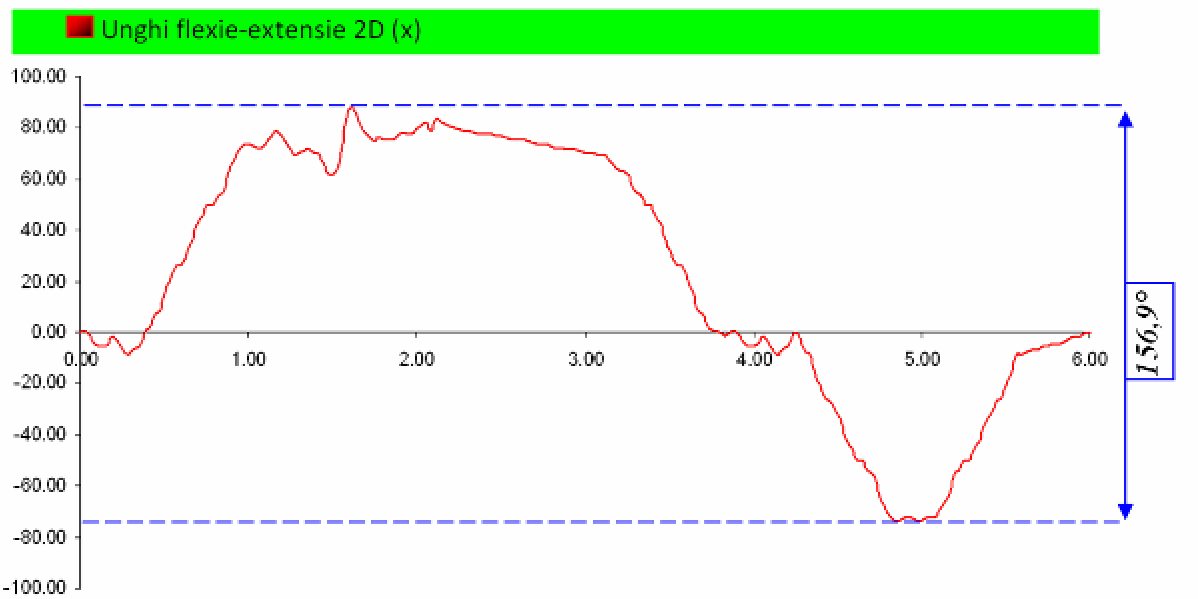

Figure 9. Flexion/Extension angular amplitude developed by using this robotic system

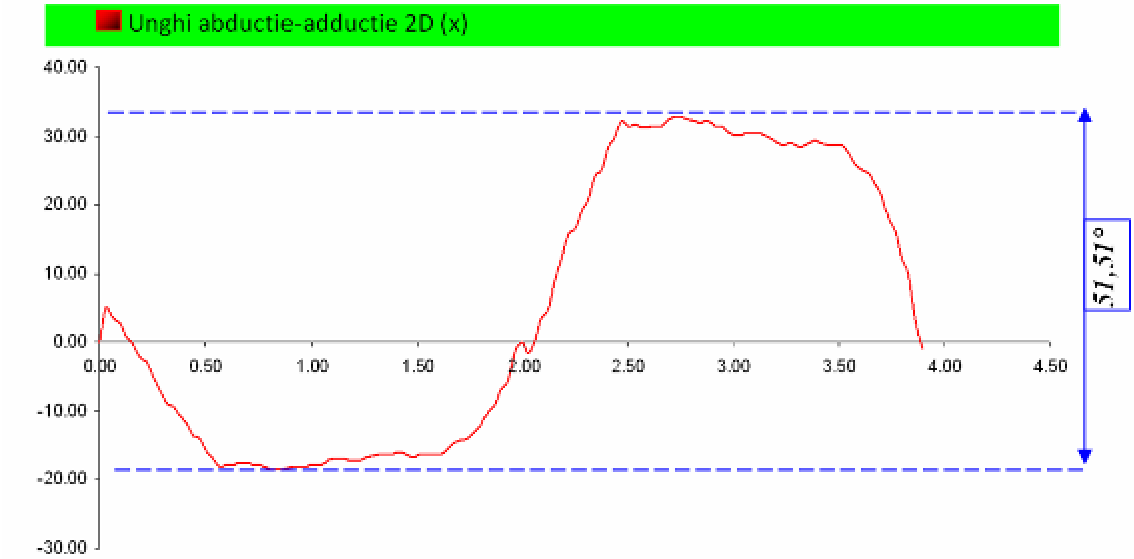

Figure 10. Abduction/Adduction angular amplitude developed by using this robotic system

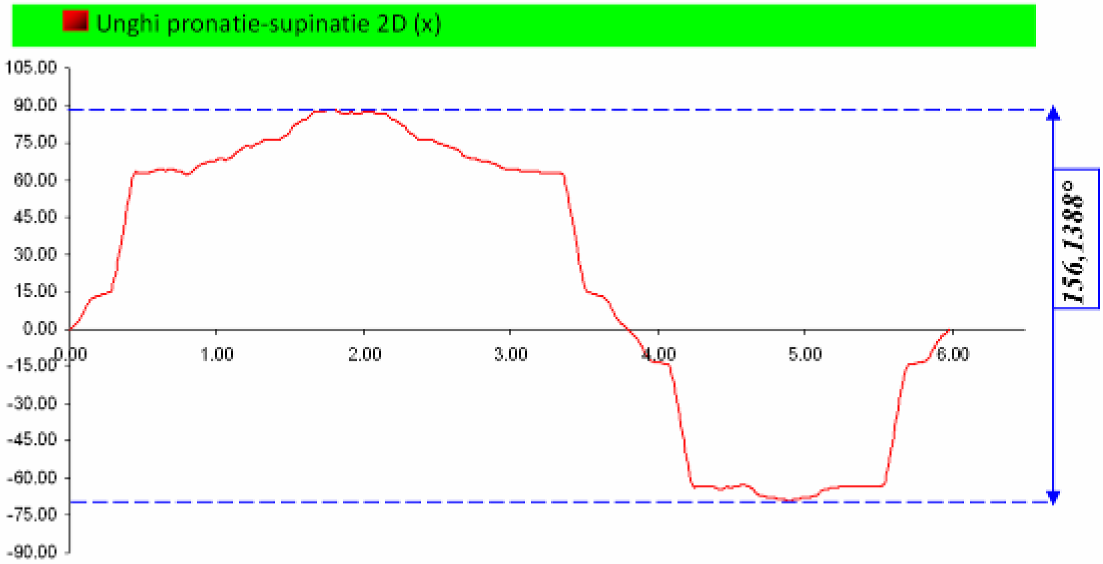

Figure 11. Pronation/Supination angular amplitude developed by using this robotic system

By using the SIMI motion analysis equipment, the robotic system prototype designed for human upper limb recovery was validated through this experimental motion analysis.

One can implement human upper limb kineto-therapeutical recovery procedures onto this robotic system.

The SIMI Motion equipment can be used for other mobile systems which develop planar movements in different domains, such as industry fields (e.g. Industrial robots), biomechanics, medicine, sports, etc.

5. ACKNOWLEDGEMENTS

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References

[1] Buzescu Al., Scurtu L. Anatomie si biomecanica. Editura A.N. E.F.S. 1999.
[2] SIMI Motion Analysis User Manual 2006.
[3] Copiluşi C. Cercetări privind sisteme mecanice aplicabile în medicină. PhD. Thesis. Craiova, 2009.
[4] Dumitru N., Nanu Ghe., Vintilă D. Mecanisme şi transmisii mecanice. Tehnici de modelare clasice şi moderne. Editura Didactică şi Pedagogică. Bucureşti. 2008.
[5] Freivalds A. Biomechanics of the upper limbs. CRC Press, 2004.
[6] Gopura R., Arachchilage R. C., Kazuo K. EMG-Based Control of an Exoskeleton Robot for Human Forearm, IEEE International Conference on Robotics and Automation, USA, 2008.
[7] Kazuo Kiguchi, Takakazu T., Toshio F. Neuro-Fuzzy Control of a Robotic Exoskeleton With EMG Signals. IEEE Transactions on Fuzzy Systems. 2004
[8] Kazuo Kiguchi, Toshio F. A 3 DOF Exoskeleton for Upper Limb Motion Assist: Consideration of the Effect of Bi-articular Muscles. ICRA 2004.
[9] McCracken T. Nou atlas de anatomie umană. Editura Aquilla. 2009.
[10] Moreno, J.C., Rocon, E., Ruiz, A., Brunetti, F., Pons, J.L. Design and implementation of an inertial measurement unit for control of artificial limbs: application on leg orthoses. Sensors and Actuators. 2006.
[11] Nenciu G. Biomecanica în educaţie fizică şi sport. Aspecte generale., Universitatea Spiru Haret, Editura Fundaţia România de Mâine, Bucureşti, 2005.
[12] Perry, J.C. Design and development of a 7 degree-of-freedom powered exoskeleton for the upper limb. PhD Dissertation, University of Washington, 2006.
[13] Schiele, A., van der Helm, F.C.T. Kinematic design to improve ergonomics in human machine interaction. IEEE Transactions on Neural Systems and Rehabilitation Engineering, 2006.
[14] Schiele, A., Visentin, G. The ESA human arm exoskeleton for space robotics telepresence. 7th International Symposium on Artificial Intelligence, Robotics and Automation, 2003.
[15] T. Nef, M. Mihelj, G. Colombo, R. Riener. ARMin – Robot for rehabilitation of the upper extremities. IEEE Conference on Robotics and Automation, ICRA, 2006.
[16] Tsagarakis, N.G., Caldwell, D.G. Development and control of a physiotherapy and training exercise facility for the upper limb using soft actuators. Proceedings of IEEE International Conference on Advanced Robotics, Portugal, 2003.
[17] Tsagarakis, N.G., Caldwell, D.G. Development and control of a soft-actuated exoskeleton for use in physiotherapy and training. Journal of Autonomous Robots, Special Issue on Rehabilitation Robotic, 2003.