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MECHANICAL REQUIREMENTS USED IN NUMERICAL ANALYSIS OF THE HUMAN LOCOMOTION

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Abstract: *A new rehabilitation mechatronical device equipped with suitable inertial sensors is presented, which enables training of a leg affected by strokes or injuries, in coordination with the movements of the other, normal, leg. This simple 1-DOF device can be included in the category of rehabilitation robotics. The main purpose is acquiring and implementation of an intelligent orthesis used for recovery training of the subject with neuromotor problems. It is destined especially to inferior and superior limbs joints recovery but performing the corresponding exercises will affect also the muscles. It will be conceived in a modular way (the mechanic module, the electronic module and the interface module). It is attached to the leg or hand, in the area that need recovery; it is programmed for each subject depending on the program type of every subject. It is made from easy and unassuming materials. As it was demonstrated as well in the evaluation of the actual status, this project's subject is compliant with the European and world trends and priorities for developing robotics systems for medical recovery. So, thru this research work, we want to design, to realize and to implement mechatronical system, which could help people with a specific neuro-motory rehabilitation therapy.*
Keywords: *medical rehabilitation, orthosis, stresses state, finite element modelling and analysis.*

1. INTRODUCTION

As defined in the Rehabilitation Act of 1973 *Rehabilitation engineering* means the systematic application of engineering sciences to design, develop, adapt, test, evaluate, apply, and distribute technological solutions to problems confronted by individuals with disabilities in functional areas, such as mobility, communications, hearing, vision, and cognition, and in activities associated with employment, independent living, education, and integration into the community. Rehabilitation technology means the systematic application of technologies, engineering methodologies, or scientific principles to meet the needs of, and address the barriers confronted by, individuals with disabilities in areas that include education, rehabilitation, employment, transportation, independent living, and recreation. The term includes rehabilitation engineering, assistive technology devices, and assistive technology services.
As a branch of the rehabilitation engineering, *rehabilitations mechatronics* is a special field concentrated on machines that could be used for helping people to get on feet after a severe physique trauma. Rehabilitation robotics exists for solving serious problems, which appear in physiotherapeutic, and already the results are miraculous in many cases. The benefits of rehabilitation robotics are many. In common, physiotherapeutic, many therapists work with a single patient, for according him proper attention and for helping him reach the closest support. An exoskeleton robot, like the one we want to realize and implement, permits rehabilitation much more exact, the robot can give the support and the patient's way of walking. The therapist can watch many patients' exercises in the same time. In addition, using this type of robots takes in count the training conditions of the patient, watching his progress, but also helps by decreasing the stress of working with a human therapist.
Within the medical rehabilitation a specific category is represented by the persons who have suffered neural-motor injuries. In order to improve the motor functions or to diminish the symptoms of the disease, the orthoses are used for quite a long time by now.
The present work is part of the research project ID_147, financed by the Romanian National Council for Scientific Research in Higher Education and developed at *Transilvania* University of Brasov. The project aims to develop and implement an intelligent orthosis for the rehabilitation of the inferior/ superior articulations of the persons suffering of neural-motor problems. The training of the injured member is done by the information received from the healthy member, through a command and control unit [1]. The device is attached to the injured arm/ leg, in the region the rehabilitation is required and it may be programmed in terms of the desired task.

2. ESTABLISH CONSTRUCTIVE SCHEME

First we established the technique as physical therapy recovery. It will apply to a subject in seated position, which makes recovery of a leg that needs rehabilitation, while the other foot operating properly. Recovery will be in training by copying the movements of the healthy leg (figure 1).
Control system to ensure proper synchronization between the movements as the foot subjected to recovery, performed using Orthotics presented in previous chapters, and leg valid. Orthotics will perform, with an adjustable delay time, the movement of the knee, with amplitude, velocity and angular acceleration dictated by the other foot. To achieve these goals was considered a control scheme with the structure shown in figure 2.

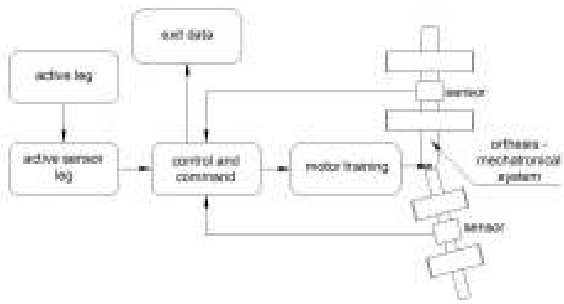

Figure 1: Block diagram of the device designed

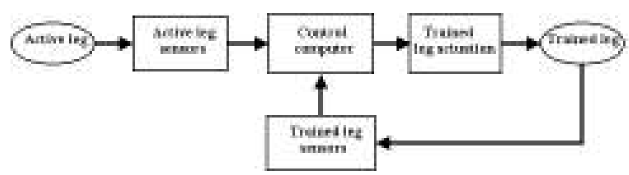

Figure 2: Block diagram of the system of command and control

In designing the mechanical system design shall have regard primarily *anthropomorphic dimensions* of the human body in seated position [3], according to the following figure:

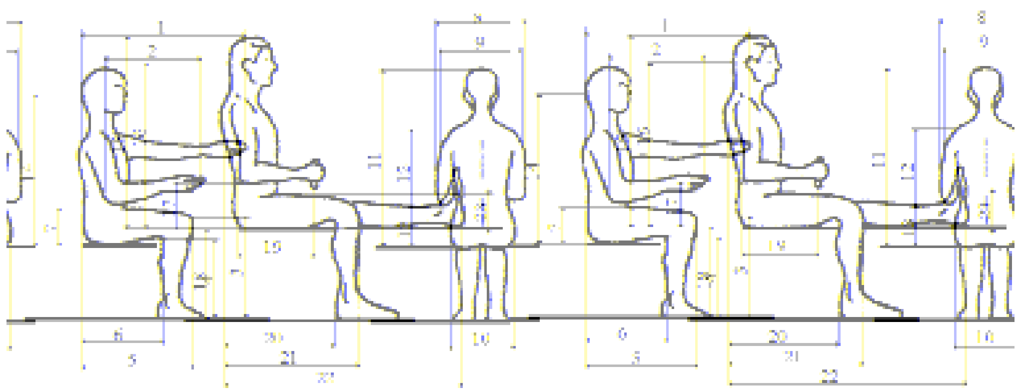

Figure 3. Anthropomorphic data of the human body in seated position

Maximum movements of the legs [3]
Studying the movements of the legs in some ways it was found that the movement hypotension is measured from the vertical amplitude exceeding 130 ° forward and an amplitude of 180 degrees when the leg wobbles back and forth. The seated position, moving outward leg spread does not exceed an angle of 45 °. Also in this position (the knee pivot) foot leg can be moved (left-right) with an angle of 30 ° and prior to an angle of 80 ° ÷ 90 °, the optimum angle in the latter situation, exceeding 45 ° (figure 4).

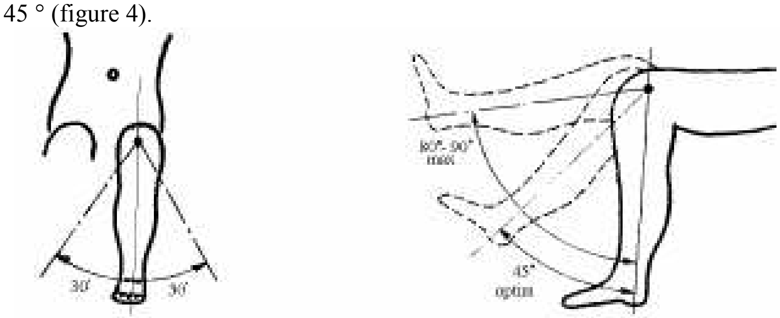

Figure 4. Maximum angle of movement of the leg

3. REQUIREMENTS FOR NUMERICAL ANALYSIS

According to Vaughan's Haz and Andrews (1982), there are two major ways in which the description of rigid body dynamics associated anatomical bodies. The first method is the direct dynamics method, dynamic parameters that are exercised in a biomechanical system are known and the objective is to determine which kinematics parameters resulting from the movements that arise in the system. The second method is given the inverse dynamics method, kinematic data of the biomechanical system are defined in detail and the aim is to determine dynamic parameters that cause the movement system [2].

The method uses inverse dynamics of rigid body models to represent the mechanical behavior of Pendulums in connection, or more specifically, the members of the human body where, anthropometric parameters, dynamic parameters and kinematics parameters of body segments are used as input for system equations of dynamic equilibrium, to determine the internal reaction forces and moments that cause the movement system (figure 5). Inverse dynamics method involves the use of specific conditions, regardless of the body segment concerned. These conditions are:

- human body is divided into individual anatomical segments;
- segments are considered rigid bodies with mass concentrated in their center of gravity;
- anthropometric parameters of segments are considered constant during movement;
- air friction is minimal;
- forces of friction with the ground and the joints are considered void;
- speed of the whole system is considered constant;
- walking is considered a cycle repetitive and symmetrical for both legs.

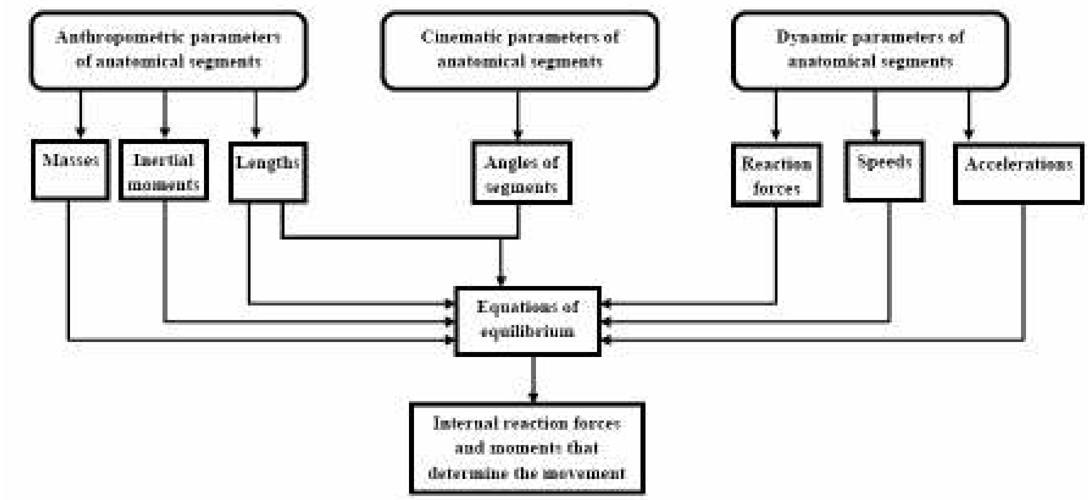

Figure 5. The principle scheme of implementation of inverse dynamics method for expressing the dynamics of solid rigid bodies associated anatomical

According to Figure 5, to determine the internal reaction forces and moments that determine the movement of a segment, the dynamic equilibrium equations involved and anthropometric parameters. Most of these parameters are the result of lengthy investigations, the doctors, the human bodies and is mediating the results achieved by human factors. Thus, it was to obtain generalized scaling factors, the length and weight for each segment of the human body part. Only height and weight of human subjects can be measured directly for each human subject in hand [4].

In Table 2 are represented anthropometric parameters and scaling factors for the main segments of the human body for subjects older than 18 years [5], where: L - length of segment [m], c - the length scaling factor, H - total height human body [m], m - mass segment [kg], M - total mass of human subject [kg], I - moment of inertia of the segment, $I = \%I \cdot m \cdot L^2$ [kg·m^2].

Tabel 1. Anthropometric parameters

Subjects older than 18 years				
Body Segment	**Length L [m] = c·H**	**Mass m [kg] = %·M**	**Position of center of gravity to point distal %·L**	**Moment of inertia %I [kg·m^2]**
Head	0,126	7,8	50	49,5
Body	0,312	49,7	50	50,3
Arm	0,188	2,8	56,4	32,2
Forearm	0,146	1,6	55	30,3
Hand	0,108	0,6	50	39,7
Thigh	0,265	10	59,05	32,3
Lower foot	0,226	4,65	56.05	30,2
Foot	0,152	1,45	50,85	47,5

To determine the parameters of kinematics method are used both video and goniometry method, or a combination of the two methods. Usually the first method is used if the human subject is underway to determine the approach angle of heel and the ground. The method involves the use of goniometry digital and aims to determine in real time as the angles formed between the anatomical segments, both static and dynamic.
If walking, dynamic parameters can be determined using a force plate (for determination of soil reaction forces on foot) and a set of accelerometers (for determining the linear acceleration for each segment anatomical part) [4].
Inverse dynamics method, used for biomechanical modeling of the anatomical systems, reduces the body in a rigid solid. According to literature, a sound system includes two or more rigid bodies linked by ties. These links, which made a system more rigid, are called internal links. In addition, if a sound system of rigid external links exist between the system and other bodies outside the system. By applying axiom links will appear in the external reaction and respond accordingly interior. For a system of rigid bodies are in balance, every body in the system must be in balance. Based on this finding, inverse dynamics method provides individual treatment of each rigid system and studies its equilibrium under the action of external forces and the outer and inner connecting incumbent.
By separating bodies, internal links are replaced by interior reaction which, under the principle of action and reaction is equal in magnitude and opposite in sense to the two separate rigid solid.
Thus, all these data in the composition of dynamic equilibrium equations of a rigid solid. Equations used by the inverse dynamics method to obtain reaction forces and moments on any joints, are the equations of dynamic equilibrium resulting from the use of the principle of Newton - Euler rigid solid [4].
Inverse dynamics method is a calculation technique that allows understanding of movement, but has some disadvantages [5]:

- is based on a number of assumptions which are not always valid, such as frictional force between the surfaces are in contact if the joints where segments of the human body, weight distribution is not uniform and not concentrated in one single point;
- measurement errors introduced by: incorrect placement of landmarks (markers) on areas of interest (lower limb joints), motion parts during movement in humans, improper alignment of the motion analysis system to the force plate;
- anthropometric values of human body segments are approximated and generalized, as proportions of body segments may be different for humans with a high or low body weight, children and patients with impaired motor neuron;
- propagation of errors - errors in calculating the distal zone propagates and the calculations for the proximal;
- can be determined only in joint reaction forces, net muscle moment and power exerted by the musculature;
- cannot distinguish muscle participating in bipedal locomotion, it can cause moments of flexion or extension of groups of muscles, but cannot provide information on each activity be it flexor or extensor muscles.

4. CONCLUSION

The project's theme lies between the tendency and European and World priorities of development of some informatics' systems of assistance of handicapped people or for the drawback people. The complexity of this, the fact that involves specialists from many domains (engineering, medicine, sports), make that this could be seen like a fundamental theme of research.

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