Dynamical Model for an Original Mechatronical Rehabilitation System

DANIELA MARIANA BARBU; ION BARBU
Precision Mechanics and Mechatronics Department
Transilvania University of Brasov
Eroilor 29 Boulevard, Brasov
ROMANIA
dbarbu@unitbv.ro   http://www.unitbv.ro

Abstract: - This paper presents a new, intelligent and portable active knee rehabilitation orthotic device designed to train stroke patients to correct knee hyperextension during stance and stiff-legged gait. The knee brace provides variable damping controlled in ways that foster motor recovery in stroke subjects. Furthermore, the knee brace is used to assist in knee control during swing, i.e. to allow patients to achieve adequate knee flexion for toe clearance and adequate knee extension in preparation to heel strike.

Key-Words: - Modeling, Simulation, Mechatronics, Rehabilitation System

1 Introduction

As is described by Elsevier, *Mechatronics* is the synergistic combination of precision mechanical engineering, electronic control and systems thinking in the design of products and manufacturing processes. It relates to the design of systems, devices and products aimed at achieving an optimal balance between basic mechanical structure and its overall control. [1] An emerging variant of this field is *Biomechatronics*, which is an applied interdisciplinary science that aims to integrate mechanical elements, electronics and parts of biological organisms. Biomechatronics includes the aspects of biology, mechanics, and electronics. It also encompasses the fields of robotics and neuroscience.

The goal of these experiments is to make devices that interact with human muscle, skeleton, and nervous systems. The end result is that the devices will help with human motor control that was lost or impaired by trauma, disease or birth defects. [1]

On the other hand, a *robot* as a mechatronical product is just a device made to fulfill a specific task or a series of tasks. Robots are used in many applications, from fun to industry or in domestic field. These application domains are constructions, the rehabilitation of sick people, trade, transportation and carrying of goods, local administration, environment protection and agriculture, supervision, inspection, radiation protection and intervention in disaster cases, hotels and restaurants, in medicine, in household, hobby and spending the spare time. In medicine, robotic systems were implemented for the ecography diagnosis, robotic systems for neurosurgery intervention, telemanipulators for laparoscopy surgeon, robocars for the transportation of sick people that can't move, robocars for drugs, food, drinks and bed sheets, robocars for cleaning activities and disinfection in hospitals, robotic systems for simulation preparation before an operation of surgery interventions, etc. [2]

Rehabilitation engineering, as is described in Wikipedia, is the systematic application of engineering sciences to design, develop, adapt, test, evaluate, apply, and distribute technological solutions to problems confronted by individuals with disabilities. Functional areas addressed through rehabilitation engineering may include mobility, communications, hearing, vision, and cognition, and activities associated with employment, independent living, education, and integration into the community. The rehabilitation process for people with disabilities often entails the design of assistive devices such as walking aids intended to promote inclusion of their users into the mainstream of society, commerce, and recreation. [2]

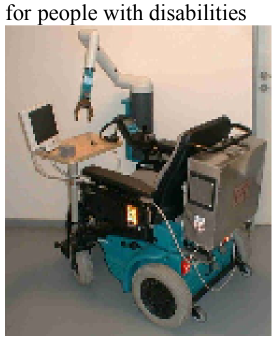
As a branch of the rehabilitation engineering, *rehabilitations mechatronics* is a special field concentrated on machines that could be used for helping people to get on feet after a severe physique trauma. Rehabilitation robotics exists for solving serious problems, which appear in physiotherapeutic, 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. [4]

For rehabilitation could be identified the following applications: folding wheel chair that can be introduced in a car, manipulator for paralytic patients, vehicle for blind people, etc.

Intelligent wheel chair

Assisted robotized system for people with disabilities

Assisted system for walking Vaseda University



System for Helping the Deaf and Blind

Fig. 1. Examples for rehabilitation mechatronics

An *orthosis* is a device that is applied to a part of the body to correct deformity, improve function, or relieve symptoms of a disease. This may be an externally applied device, which supports or assists the musculo-neuro-skeletal system.
Orthotics is an allied health profession that is concerned with the design, development, fitting and manufacturing of orthoses, which are devices that support or correct musculoskeletal deformities and/or abnormalities of the human body.
The term is derived from the "ortho", meaning to straighten. Sciences such as materials engineering, gait analysis, anatomy and physiology, and psychology contribute to the work done by orthotists, professionals engaged in the field of orthotics. Individuals who benefit from a complex orthosis may have an orthopedic condition such as scoliosis or a fracture or have sustained a physical impairment from a stroke or spinal cord injury, or a congenital abnormality such as spina bifida or cerebral palsy. When appropriately prescribed, these orthoses can decrease pain and increase stability in an unstable joint, along with preventing potential progression or development of a deformity. Improved quality of life often results from the application of the principles of orthotics. More recently, the term cognitive orthotics has been applied to assistive technology to correct cognitive functions.
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. We speak about the knee and elbows joint, but the system can be adapted to the hands, ankles, shoulders or haunches joint. Therefore, our intention to realize a robotic mechanical-electronic system, which is a device that helps an organ to have a proper functionality, makes this project to be very important for some category of people. Here we speak about: people that suffered an accident and have lost partially or totally the possibility of moving a leg or a hand; people that suffered surgery interventions and who need a recovery technique of locomotion; sportsmen that need training or need medical recovery after an accident; old people which need neuro-motory rehabilitation exercises; children with neuro-muscular distrophy; people that by some causes have lost temporary the locomotion function, etc.
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 draw back 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.

2 Our Proposed Model for Medical Rehabilitation

In this research we want to project, realize and implement a mechatronical system (an intelligent robotized orthesis), what shall can help the persons finder out in a certain therapy regenerative neuro-motory. We follow here in chief the knee-joins and the elbow, but the system can be adapted to hand joint, or the ankle, the shoulder or the thigh.
Due to the fact that the device on which want to achieve helps in the execution human functions, respectively one locomotors, can say as he shall have the roles of locomotory orhesis.
In the adoption of optimum model is due to consider several factors:

a. The bipedal representation

The skeleton of the personage is represented in the likeness of hierarchies of rigid segments connected through these joints a joint compels the extremities of which segments by-paths bended to remain conjunctively all through. This is achieved default with help of the Denavit Hartenberg notation, through the fact that each the segment is expressed thru the local mark. The relative motion of the segment in report with his father achieves maximum 3 degrees of in a freedom rotation, the one 3 graduate of freedom for translation am excluded because the extremities of the 2 segments are due to remain conjunctively. [3]

The biped virtual personage is a model simplified of an a biped which robot behaves 17 degrees freedom with coplanar segments. The biped is described as an articulate structure defined in many coordinates (14 angles) in the notation Denavit Hartenberg. We associate the biped a vector of state, which is the vector of articular sprocket of robot again the vector of joint speed. The vector of state contains 28 of components. A motion is definite as a sequence of vectors of state temporally.

b. The joint modeling

The models of the joints comprise the brawn and weaved flabbily from around them self. The quality of the subject gait depends on two major factors. One he is associated restrictively functional and structural enforced of proper locomotory systems and second is associated his possibility put on the go an effective strategy motional. The forces that react on the human body in the time gait can be dimidiate categories: Internal forces and external (gravitational and of reaction ale the soil). The gravitational what forces acts on each segments are determinate of table and of the localization barycenters. These can be calculating in company with the moments of inertia of the segments using techniques of estimate and anthropomorphic sizes. The internal forces the by-paths are estimate analytically. The analytic methods use approach of classic mechanics and approximations of model. Is presupposed that the forces and the bindery moments among segments maintain two segments adjacent in same dynamic as good as one state before their imaginary separation. Using this hypothesis in company with the anatomic information and functional about the flabby tissues, I can assume the internal which shipments appear temporally gait. For evaluation, relevance is, also, and the estimation of the energy. In this sense are definite many experiments which have as the aims the settlement of power cost of the total of movement as well as the energy mechanic from joints. The cost the total of movement can be caused experimentally. When a model a mechanic of a human body is defined as string of rigid what segments transmit forte and couples, the energy these mechanical segments and the thing the mechanic accomplished of they can be calculating. [3]

c. The establish of the constructive scheme

In fore rank we established the technique regenerative as be the kinetoterapy. It is shall applied of a subject in the seated sprocket, carry does the recovery what foot requires the medical recovery, while other foot operates in natural parameters. The recovery shall consist in the practice foot through the duplication motions of the healthy foot. (fig. 2) [4]

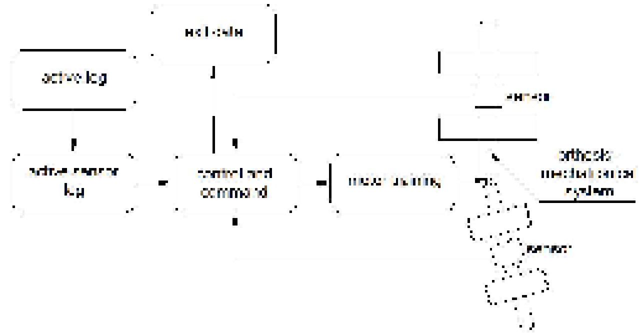


Fig. 2. The Constructive Scheme

3 Proposed Dynamical Model

Methodical analysis of mechanical systems using MBS software involves going through three stages: preprocessing (modeling system), processing (rolling model); post processing (processing results). In systems study using dynamic simulation is frequently addressed three working models:

- structural model, containing only the elements and links between them (kinematic couples) and established the determined condition of movement transmission (system mobility);
- kinematic model, which, in addition to the structural and geometric parameters includes defining the system and to establish laws of motion (position, speed and acceleration) of elements in the movement of time (known / required) leader element;
- dynamic model, which, in addition to the kinematic model, and contains the mass of elements (mass, moments and products of inertia) and the forces (external and internal) acting on the system, this model determines the movement elements under the action of forces.

To simulate the dynamics of the mechanical system of orthosis was used a specialized software MBS (multi-body systems).

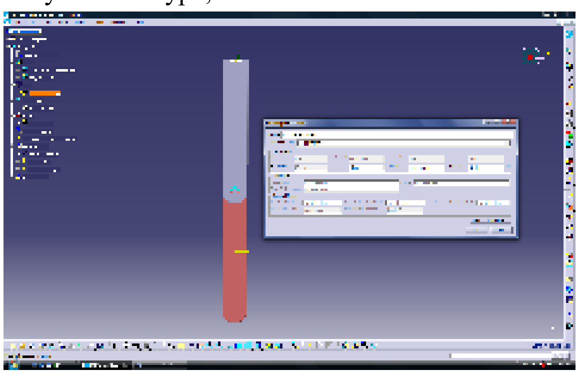
4 Results

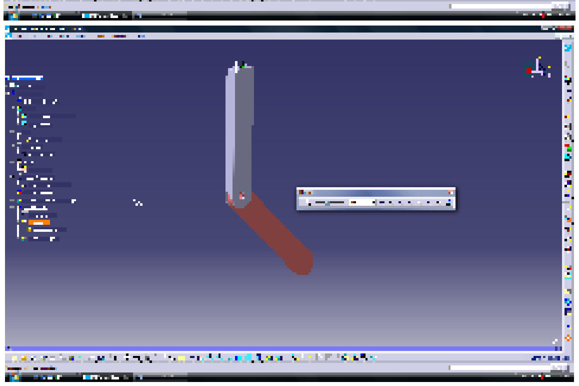
The method of analysis of mechanical systems using MBS software, involves three steps: preprocessing (modeling system), processing (rolling type), post-processing (processing results). [4]

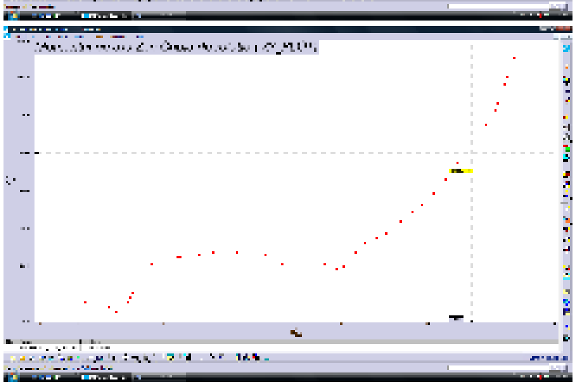
In the study of systems using dynamic simulation models are often approached three working models:

- the structural model that contains only elements of the system and links between them (kinematic couplings) and which shall be provided determinabilității transmission movement (mobility system);
- the kinematic model, which, in addition to the structural model, includes geometric parameters that

define the system and that moving to the laws of motion (position, velocity and acceleration) of the elements in function of movement type (known / required) of the leader element;
- the dynamic model, which, in addition to the kinematic model contains elements and characteristics of mass (mass, moments and products of inertia), and the system of forces (internal and external) acting on the system, the model is determined movement elements in the forces.
For dynamic simulation of mechanical system using specialized software MBS (multi-body systems) the steps are:
- CAD modeling of mechanical system components of orthotics;
- calculate, using MBS software masico-inertial characteristics of bodies, mass, center of mass position;
- creating connections between bodies (geometric restrictions on the movement of bodies) - the geometric restrictions in movement kinematics coupling bodies used cylindrical type;







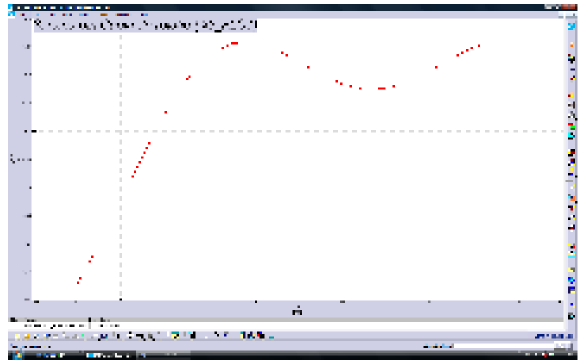


Fig. 3. The results of the dinamical simulation

- introducing the law of motion of the body cell, using a hyperbolic function for the calculation engine when needed and the tasks that appear in the joint system.

5 Conclusion

The project is in final stage of progress, as do experimental research. He made his virtual prototyping, and we expect good results and the experimental. We hope that the device you plan to create more persons to assist in the recovery technique locomotorie.

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