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BOOK OF ABSTRACTS

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In Memoriam

Yuli Toshev, Professor of Biomechanics, Head of Department "Biomechanics of motion and telemanipulators", Institute of Mechanics, Bulgarian Academy of Sciences

Prof. Yuli Toshev died in Sofia on April 22, 2008. He was born in Svishtov on December 7, 1945. He obtained his Master of Sciences degree in Computer Science in Bulgaria (1968), his PhD in 1975, and a DSc degree in Biomechanics in 1995. At the time of his death, he was a Full Professor in Biomechanics and Robotics in both France and Bulgaria.

Prof. Yuli Toshev was inextricably bounded up with the creation, consolidation and the development of the biomechanics in Bulgaria. He defended the first PhD thesis on biomechanics in Bulgaria at the end of the 70s and later headed the first department in the field of biomechanics in Bulgaria, currently Department "Biomechanics of motion and telemanipulators", at the Institute of Mechanics and Biomechanics, Bulgarian Academy of Sciences.

Prof. Yuli Toshev is author and co-author of 11 books and textbooks (7 in France) and over 200 scientific articles. He headed more than 15 international scientific contracts in the field of Biomechanics and Tele-robotics with partners from Poland, Russia, France, United Kingdom, and Belgium, as well as of 18 scientific elaborations and contracts supported by Bulgarian Science Fund. To the last he was a contractor of Network of Excellence – 4M, European project of FP6.

He is a foundation-member and president of the Bulgarian Society of Biomechanics (1991), member of International and European Societies of Biomechanics. Prof. Toshev was a man who epitomized the philosophy of the ISB: maintain the highest academic standards, promote biomechanics at the international level, and serve the profession that you represent.

In 1992 he founded the Department "Biomechanics and Robotics" at the Faculty of Engineering at the Southwest University in Blagoevgrad, Bulgaria. Up to 2002 about 260 MSc degrees on biomechanics and biomedical engineering were obtained there under his guidance.

Prof. Toshev was a strong believer in international contacts, and spent time in many different labs including University of Paris-South, Massachusetts Institute of Technology (MIT), Penn State University, National Institute of Applied Sciences, Rennes, Université Catholique de Louvain, Belgium, University of Cardiff, Wales and University of Reims, France. Besides working with colleagues at these institutions, Prof Toshev was a frequent attendee at ISB Congresses.

Towards the end of his life, Prof. Toshev devoted considerable time to the creation of a new journal, "Series on Biomechanics" (http://www.biomechanics-bg.org/).

Prof. Toshev was a leading biomechanist who promoted research with enthusiasm and creativity: he will be sorely missed.

Indeterminate problems in biomechanics: models of muscles and their control

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Movements of human limbs are performed by many muscles, with different mechanical peculiarities, which rotate the joints as a result of contractions. Experimental evidences exist that human perform well-trained, daily movements using similar strategies, both concerning motion kinematics and participation of different muscles. This suggests that an optimal control is developed during training. Since the number of muscles exceeds the number of equations for static or dynamic equilibrium, optimization methods have to be used. A problem is how to formulate the objective function, so that the predicted muscle forces to correspond to experimentally observed muscle activities (usually estimated by processed surface EMGs). Other problem is how to model muscle force. In macro-biomechanical limb models each muscle is represented as a single force generator. Its force can be independent on the length and the contraction velocity of the muscle. Other possibility is to use rheological (Hill-type) models which represent a muscle as a combination of elastic and contractile elements and the muscle force is expressed as a function of muscle current length, contraction velocity and parameter named "activation" that reflects the percent of active muscle fibers. Here the muscle force is supposed to be controlled by a single, continuous signal. In fact, the smallest functional muscle unit is the MU and its force is controlled by under-threshold electrical impulses with variable inter-pulse intervals. The force of the whole muscle is a sum of the forces of all its MUs and is regulated by two mechanisms - by changing the number and type of active MUs and the stimulation frequency of the active MUs, i.e. recruitment and rate coding. Different models of upper and lower human limb are considered (with 1, 2 and 3 degrees of freedom) and indeterminate problems are solved analytically (using Lagrange multipliers method) and numerically. The applicability of different optimization functions is discussed. A realistic muscle model composed by MUs and MotCo software (http://www.motco.info/) for its simulation are presented. A hierarchical genetic algorithm (HGA) is implemented here. The results of simulation of flexion/extension motions in the elbow joint are presented and compared with other approaches for solving indeterminate problems.

Computerized investigations on kinetics of bioconversions in fixed films

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The present work is dedicated to the development of "joint strategy", which incorporates three constituents. The System approach as a methodology of efficient use of the knowledge about the nature of the investigated system forms the basis. The second level is occupied with design of experiments with its method for rational planning and analysis of experimental activity and on the top - is computer science with its potentiality in problem oriented software. Unifying all these constituents to one whole, this strategy offers rationalization of all the steps in kinetics research, including elimination of influence of mechanics to the biokinetics, making the biofilms the core of each BPSff, decomposition of the biofilm to subsystems, its mathematical description and in formation of prescription of further steps of the research activity.

Joint strategy is tested on the concrete bioconversion process – bacterial oxidation of ferrous ion to ferric ion in fixed film formed by a strain of *Thiobacillus ferrooxidans* in a biodisk reactor. This system is suitable to be used as a test due to its simplicity by using one substrate ($FeSO_4$) for only one product ($FeSO_4$), with the special properties of the formed biofilm and its widespread practical use in hydrometallurgy and mine wastewater treatment. Implementation of the "joint strategy" to each step of research allows revelation of its potentialities. Along with above mentioned positive impacts on research activity, in this concrete case the strategy prove to be very useful in the analysis of mechanisms and applying some new method of their mathematical modeling, which is very important in biokinetics investigations.

Methods in hemorheology

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The purpose is to overview existing and introduce new methods and instruments for assessing mechanical properties of blood and red blood cells.

A great variety of instruments and methods to study hemorheological parameters under conditions close to physiological are currently used: viscometers, different techniques for assessment of RBC deformability and aggregation. More of these methods allow determining the average characteristics, measuring erythrocyte deformability and their ability to change their shape under force acting on the cell as a whole. Atomic force microscopy (AFM) permits to investigate living cells and cellular structures per high-resolution visualization and to assess local mechanical properties (elasticity, rigidity index and surface topography of the membrane). Nanoindentors assess deformation and Young modulus of RBCs, measured from nanometers to millimeters. Different biochips and pumps are developed to study cell rolling, adhesion and migration which mimic *in vivo* vascular flow.

The nanoindentors evaluate RBC hardness and modulus versus displacement in the surface in nanometers with high accuracy. AFM enables to assess the morphological characteristics of cells and the surface topography of erythrocyte membranes as well as their rigidity index and modulus of elasticity. Various cellular processes, such as elasticity and mobility of the surface layers, adhesion, molecular bonding and electrical charge can be studied more deeply through AFM measurements of the mechanical properties. AFM allows measuring the adhesion forces which take place during the interaction of the probe with the surface and gives an opportunity to determine the localization of receptors or other structures on the membrane surface in the case of the modified probe.

The change of the cells structural and mechanical properties is a consequence of the initiation and progression of certain diseases. The new methods might give a new insight into evaluation of the viscoelastic properties of RBC for certain disease. They contribute to study virus-cell interactions as well as DNA, RNA, various tissues and organs as well as to mechanical properties evaluation during cell migration, differentiation and ageing and analyse the role of cell rolling, adhesion, migration and transmigration of cells and different adhesion molecules.

The influence of grafted polyzwiterions on the viscoelastic mechanical properties of hernia meshes

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One dimensional relaxation experiments with mesh samples from Surgimesh (Aspi Medical, France) and Tecnomesh *(*TecnoMedic GmbH,Germany) cut in two orthogonal directions - parallel to the column of loops and along the rows of loops were performed. Lipoidlike poly (3-dimethyl (methacryloyloxyethyl)) ammonium propane sulfonate (PDMAPS) was used to graft these available in clinical practice polypropylene hernia meshes - Surgimesh and Tecnomesh in order to improve their bio- and blood-compatibility. The viscoelastic properties of modified and non modified meshes relaxed at physiological and above physiological initial strain were compared. The results obtained show that both modified with PDMAPS hernia meshes change their mechanical properties in the range of deformations and became stiffer. The changed physicomechanical properties of investigated meshes were explained using a dipole-dipole interaction between lateral polyzwiterion chains.

Stress-strain relations for rat thoracic aorta

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The stress response of the arterial system under physiological loadings is sensitive to pharmacological treatments and pathological changes and, therefore, its quantitative analysis can be applied to the assessment of drug and pathology on the cardio-vascular system. This presentation aims to present analytical expressions for the stress-strain relations using experimental data for rat thoracic aorta.

The experimental data were extracted from pressure-volume experiments at different longitudinal lengths using specially designed equipment. The experimental stress-strain relations in longitudinal, circumferential and radial directions were derived from the equilibrium equations of thin homogeneous, incompressible, and orthotropic tube.

We used a phenomenological strain energy function (SEF) of polynomial-exponential type, from which the analytical stress-strain relations were obtained. The rheological parameters of the SEF were determined using data from certain longitudinal elongation and they were verified for some different elongations. The coincidence of the theoretical and experimental stress-strain relations was very good (less than 3%).

Experimental investigation of static and dynamic mechanical properties of soft biological tissues

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The purpose of this article is to describe the development of biomechanics in Bulgaria. A detailed study is made of the achievements in experimental investigation of soft biological tissues – arteries, different types of fasciae and skin for the last 35 years. The article represents a survey of the methods of mechanics applied for the study of the static and dynamic mechanical properties of soft biological tissues**.** A special emphasis on the practical application of the obtained results were done.

Influence of incubation temperature and $CoCl_2$ concentration upon blood hemorheological properties and erythrocyte morphological parameters

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Cobalt chloride ($CoCl_2$) is a water soluble agent shown to improve hematological parameters by increasing red blood cell count, hematocrit, hemoglobin concentration in case of anemia or severe blood loss. Alternation of red blood cells (RBC) morphology and viscoelasticity are some of the basic indicators for human health, disease diagnosis and treatment. Temperature on the other hand is a critical factor for blood parameters and hemorheology. Blood viscosity increases as the temperature decreases. Changes of hematological parameters induced by exposure of blood to varying degrees of temperature are poorly studied.

We examined blood samples of conserved blood, which were incubated *in vitro* at different temperatures (4, 20 and 37ºC) and treated with different concentrations of $CoCl_2$ - 50 μM and 500 μM.

Simultaneously the apparent viscosity was measured at 37ºC of all blood samples, as well as erythrocyte morphological characteristics were evaluated. The preliminary results showed that the rheological blood properties were changed as a consequence of incubation at different temperatures and blood cell morphological alterations were detected when different $CoCl_2$ concentrations were added.

Creation and implementation of models for bioprocess system with fixed film

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This paper presents results of a rather long experience in modeling in Bioprocess Engineering, mainly in model creation and use in development of bioprocess systems with fixed films (BPSff). Special attention is paid to the terminology of this field by making attempts to justify the main notions not only in BPSff but in Bioprocess engineering as a whole. On this basis, renovated definitions are given to notions like “biocatalyst”, “bioprocess system”, “private models” in connections with “cold models”, “dead models” and “living models” as well as to the general living models.

The decisive role of the System approach in the natural (physical) and mathematical modeling of BPSff is pointed out. Experimental results obtained with active use of principles of this approach in concrete BPSff development in each steps of R&D activity are discussed. It is shown how the well known conception of research in this field formed of three steps can be enriched with a new one - the system stage. Positioned just before the last stage of practical realizations, this new section of the research chain proves to be very useful in understanding the essentials of each concrete studied bioprocess system. Such an approach can help avoiding many problems of BPSff development including the scaling up of BPSff. Some ideas are shared about future enlargement of research activity in the field of the bioprocess systems with fixed films both in the Institute of mechanics of BAS and in Biological faculty of Sofia University in continue of the Frame contract of joint research between these two institutions.

An algorithm of identification of the parameters of Michaelis-Menten model of tissue respiration based on data from Warburg-type experiments

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In Warburg - type experiments used to determine the parameters of the local oxygen consumption of intact tissue the full oxygen uptake of the tissue under study is registrated together with the oxygen tension of the suspending medium. Supposing Michaelis-Menten kinetics of tissue oxygenation an algorithm for its parameter identification is constructed. It is based on the exact solution for tissue slice respiration reported in [1]. The proposed algorithm is applied to slices of rat skeletal muscle tissue as well as to preparations of six albino-rat tissues (kidney, heart, liver, brain, diaphragm, and lung). A comparison with results obtained by use of another model is performed.

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Need of knowledge about mechanics of the bioprocess systems with fixed films as basis of new developments and innovations

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Recent our investigations has reveled the abrupt increase of the researcher interest on biofilm reactors after the 1994. Successful implementation of the system approach to the bioprocesses (BP), which occur in these bioreactors (BR) at appropriate operational (bio) regimes (OR), produced as a result the definition of the notion of "bioprocess system with fixed film" (BPSff). Being an amalgam of these three constituents (BP, BR and OR), this type of objects possesses all the characteristics to be qualified in the terms of system approach as "large systems" or "systems with "bed" structure". One of most rational decompositions of the BPSff to subsystems gives as the result a hierarchic structure in the form of a pyramid, on the base of which stands mechanical phenomena, which occur in the bioreactor.

The aim of present study is to stress on the need of the intensive research on this basic subsystem of BPSff for acquiring knowledge for prediction of the behavior of these systems as a whole. Implementation of the system process analysis reveals the most perspective directions for investigations. They are: biofilm physical properties; mode of energy input into the bioreactor; hydrodynamic regimes for biofilm formation; management of biofilm selforganization by means of mechanical coercions. They are discussed using results of our more than 30 years experience and our achievements in laboratory investigations and in industrial scale realizations of BPSff both in new developments and innovations.

Assessment of Acidithiobacillus ferroocsidans oxidation ability for ferric ions production in different modifications of nutrient medium

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The capability of Acidithiobacillus ferroocsidans to oxidize ferrous to ferric ions is well known and successfully used in ecologically friendly technologies for tail gas and waste waters treatment.

This work is part from larger study on influence of two important for that strain factors – calcium ions and acidity levels (pH). The experiment proceeds at three levels. Oxidative capacity of bacteria was assessed on the base of the average velocity of ferric ions production at different hours from bach.

The biooxidation was compared with chemical oxidation of ferrous ions without microorganisms. The results show that chemical oxidation is negligible under these conditions.

Key words: *Acidithiobacillus ferroocsidans*, ferric ions, biooxidation, pH, calcium ions

Time delay model of miRNA regulation

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In this paper we investigate the time delay model of a feedback system regulated with miRNA. Using the Hopf bifurcation theorem, we predict the occurrence of a limit cycle bifurcation for the time delay parameters. From the accomplished analytical and numerical results, it becomes clear that time delays have destabilization dynamical role.

Analytical study of the human extremities parameters via three different approaches

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We present results from three different analytical approaches for calculating of the mass-inertial characteristics of upper and lower arm, thigh and shank of the human body using 3D geometrical modeling. The results are based on the experimental data of the representative anthropological investigation of 5290 individuals (2435 males and 2855 females) of the Bulgarian population at the age between 30-40 years (Yordanov et al., 2006) as well as on our own anthropometric measurements of 50 Bulgarian men and 52 women of the same age. Wherever possible, we present also a comparison of our data with the ones available in the literature for other Caucasian and determine in what case the use of which approach is more reliable.

Prognosis, monitoring and prevention of the risk of postoperative infectious

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In light of the current understanding of the ethnological determinants and the pathophysiological mechanisms, responsible for developing of postoperative infectious complications, the authors present an own predictive model and report their two years experience findings. The main objective of our prospective study was to establish a well – motivated parameters for early identification of an risk patient populations with a predictable response to the surgery intervention and to investigate the benefits of appropriate prevention steps. Our initial attempts to use indicators, predicting the host response to major surgical intervention and our first results has proved the here discussed complex approach beneficial in the reduction of the postoperative infectious mortality and morbidity frequencies and in the early diagnosis of the postoperative infectious complications.

Analysis of controllable compliance joint with leaf spring

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In the twenty-first century robot technology will play an important role not only in industry but in human environment. Robots should have compliance for human friendliness, safety issue and relief of impacts. A controllable compliance joint of robots is developed in the present work that creates natural security in the interaction with human. Examples of novel applications for compliant joins are controlled passive walking, safe human-robot interaction and comfortable actuated prostheses and orthosis.

This work shows some ways of passive joints stiffness adjustment. For compliance control there are approached some cases of leaf springs. The key features of the joint, as torsion stiffness and range of variation of stiffness, torsion tension, admissible torque and angles of deflection are approached. There are evaluations and recommendations for design of adjustable compliant joints based on leaf springs.

Keywords: robot, controllable compliance, leaf spring, torsion

Controllability criteria in designing human assistive devices

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Motion control is complicated for people having traumas or neurological diseases. An underlying assumption in our work is that the motion of healthy people is optimal with respect to positioning accuracy, movement response, and energy expenditure. Patients need to restore their motion performance to the best possible level. We consider complex biomechatronic systems (BMS) like human with active orthosis or robotic arm that have to perform two main types of motion tasks: goal-directed movements and motion/posture stabilization. In this study, we are concerned with the latter type of motion tasks and the problem of designing optimal stabilizing control functions for them. We propose design concepts and criteria for BMS based on necessary and sufficient conditions for their robust controllability. Two examples will be given to illustrate the main features and advantages of the proposed design concepts.

Data management in gait analysis using autonomous system for control and monitoring

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In this study we describe an autonomous system for estimation of spatio-temporal parameters during walking. Based on a biomechanical model, the medio-lateral ankle rotation during stance and swing phase of walking, the stride length and velocity are estimated. Measurement's accuracy for each gait parameter was assessed using the information provided by tactile sensors between each heel strike and toe-off as well as the signal obtained from a rotational potentiometer in the ankle joint measured ankle angle. During each gait cycle, by measuring the total time when the foot remains in contact with the ground, the microcontroller estimates the forward speed and modulates the swing phase flexion and extension in order to achieve quite normal lower limb dynamics.

The research work combines hardware and software design of the intelligent control device with graphical interface for representation and analysis of the data acquired during human motion.

The system is portable, and can be carried for long periods of time, thus providing new longitudinal information such as stride-to-stride variability of gait. Several clinical applications can be proposed such as outcome evaluation after total knee or hip replacement, external prosthesis adjustment for amputees, monitoring of rehabilitation progress, gait analysis in neurological diseases, and fall risk estimation in elderly.

Keywords: Gait analysis; reference data; repeatability; parametric analysis

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Experimental and modeling investigation of muscle activities during elbow flexion with different speeds

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Muscle activation patterns change substantially depending on the movement speed, since the external joint moment, including its direction, depends on angular acceleration of moving bones. Antagonistic muscle activities are observed even when the direction of the external joint moment does not change. Therefore, other explanations, related to motor control mechanisms and properties of motor units (MUs) have to be searched for. The goal of this study is to compare the patterns of muscle EMG activities measured experimentally during voluntary elbow movements with computer simulations, to provide evidences concerning multi-burst muscle activities and to hypothesize an explanation.

Three volunteers from the University School of Physical Education in Poznań, Poland, were seated on the chair with the right upper limb fully extended in the elbow joint. From the starting, relaxed position, they were asked to flex maximally the right forearm and then passively return to the initial position. Six different speeds of movement have been implemented (30, 60, 240, 360, 500 deg/s and the maximum voluntary one). The surface EMG signals from biceps brachii (BIC) and triceps brachii (TRI) muscles and elbow angle were registered and stored. The experimental data were processed off-line with custom-made software. Three chosen movements of one subject with the slowest, medium and the maximal voluntary velocity of elbow flexion were modeled by MOTCO software (http://www.motco.info). By the use of a hierarchical genetic algorithm, this software predicts the impulsation of the MUs constituting the muscles, so that the resulting total muscles' moment matches the external joint moment given as an input.

During the slowest movements, only BIC muscle had activity and its predicted peak force was about ten times lower than the one produced during the fastest movement. The faster the movement was, the more expressed were the multi burst activities of BIC and TRI muscles. In the medium-speed movements, the antagonistic TRI activity was observed even when the joint moment did not change its direction

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Rat muscle model composed by 30 motor units - simulation of its force during different patterns of impulsation

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Muscle force is a sum of forces of muscle' motor units (MU - a motor neuron and the muscle fibers innervated by its axon). Two mechanisms exist for muscle force regulation - (1) changing of inter pulse intervals, hence of instantaneous frequency, i.e. rate coding, and (2) recruitment/decruitment of different MUs. Since in vivo experiments for studying these processes are limited, models can help. There are several models consisting of MUs. The most complicated and used in different modifications is the Fuglevand model (J.Neurophysiology, 70:2470-2488, 1993). It is based on hypothetical MUs, which individual contractions (twitches) differ only by maximal force amplitude and contraction time. The way of recruitment is modeled according to the well-known size principle (Henneman et al., J.Neurophysiology, 28:599-620, 1965).

The new muscle model consists of 30 rat MUs (10 slow, 10 fast-fatigable and 10 fast fatigue-resistant) which twitches (the mechanical contraction due to one pulse) are really measured in the Dep. of Neurophysiology, Univ. School of Physical Education, Poznan. These twitches are modeled by previously proposed by Raikova et al. (JEK, 18:741-751, 2008) 6-parameters function. The developed software for simulation of the muscle force has as inputs the parameters of the 30 twitches and arbitrary generated patterns of impulses of each MU. The force of a MU is the mathematical sum of the individual contractions due to each pulse and the force of the whole muscle is the sum of forces of all MUs.

The model is investigated by application of different impulsation schemes – regular and irregular, synchrony and asynchrony, with different lows for delay during recruitment/decruitment of the MUs. The role of slow and fast MUs is separated.

It is concluded that slow MUs develop less but more smooth force, i.e. their tetani are more fused comparing to ones of the fast MUs using the same impulsation; the non-synchronic impulsation of the MUs leads to more smooth force production; the curvature of the total muscle force during recruiting and decruiting of MUs according to the size principle depends on the chosen delay for different MUs.

Acknowledgements. This study is supported by a grant from Bulgarian Science Fund No. ДМУ 02/05.

Structure identification in motor control of human motion

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When we have to analyze or design motion control of humans, we need appropriate computer models. For control purposes, we may use properly simplified dynamic models with a reduced number of degrees of freedom. It means that, with given motion task, we have to work with models that sufficiently well represent the kinematics, dynamics, and control functions. We can generate such models employing a general 3D computer model of the human body with 16 segments. First, we define a set of variables that best characterize its dynamic performance in the required motion task. Second, driving forces/torques are properly assigned in order to achieve the required dynamic performance in an efficient way. The usual performance requirements are for positioning accuracy, movement response, and energy expenditure. Using simplified, yet realistic, models, we give two important examples to explain the basic features of our approach: the standing-up motion task and the upward posture stabilization.

Keywords: humanoid body, dynamics, control, optimization.

Phase structure of a self-learning system of movements in shooting with cross back jumped step in handball

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The report analyses the kinematics of shooting with cross back jumped step and presents a methodology for training using the cybernetic approach in the different phases of formation of the motor habit. The conclusions and recommendations are oriented towards optimization of the learning process in teaching handball.

Key words: handball, kinematics, structure, teaching.