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Special Issue
Experimental Approaches in Dynamical Analysis and Control of Mechanical Systems

Preface

Identification of system parameters is usually a very troublesome problem. It encloses a multidisciplinary approaches ranging from systems theory, methods of nonlinear dynamics, the measurement signal treatment, the experimental engineering procedures, and many other. The more the system of analysis is complicated, which is often related to its multi-dimensional modeling, the more laborious its parameters are possible to estimate. Usually, a dynamical process subject to one of the above itemized approaches behaves unpredictably, and may be identified only partially. Therefore, the Special Issue extends selected papers presented during the international conference on *Dynamical Systems – Theory and Applications* held on December 2-5, 2013 in Lodz, Poland. Main areas of modern experimental and numerical analysis taken into consideration by authors of these papers could be mentioned: bifurcations and chaos in dynamical systems, stability of dynamical systems, original numerical methods of vibration analysis, non-smooth systems, engineering systems and differential equations, control in dynamical systems, asymptotic methods in nonlinear dynamics, vibrations of lumped and continuous systems, dynamics in life sciences and bioengineering. In particular, the following areas of nonlinear dynamics and systems theory with respect to the Mathematics Subjects Classification are covered: stability, nonlinear resonances, bifurcations and instability, general systems, mathematical modeling (models of systems, model-matching), system identification, control systems and adaptive control. A brief description of contents of this Special Issue follows.

The theory of fractional calculus and the concept of fractals is studied by Abramova and Abramov. Various types of fractal nanotraps based on quasi-two-dimensional fractal structures are obtained by the method of sections. It is shown that the behavior of the deformation field for the coupled state of the fractal nano-system is essentially different from the deformation field for the uncoupled state. It is proposed to use fractal nanotraps for trapping individual particles or groups of particles in order to study their physical properties. Stanczyk and Awrejcewicz present results of investigations of real six-legged robot called hexapod. Due to specific construction of legs having three degrees-of-freedom, a prototype allows to model gait of reptiles and insects. Applied mathematical model yields identification of the angular velocity, acceleration and moments generated by each of the robot cells, separately. As a result it is possible to determine quality coefficients of different gait patterns of the robot, i.e. maximal speed or maximal load depending on the number of moving legs. Obtained results are confronted with a theoretical model of differential equations regulating gait of the hexapod.

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A study by Osinski and Rumianek is carried out to develop the methods of describing some properties of investigated materials. The knowledge of basic materials and gas pressure formed during foaming using the theory of hyperplastic materials, and in particular, Ogden's model and its modifications is extended. The aim also goes on to analyze the possibility of energy dissipation between a pedestrian and a vehicle on impact. The energy created during the impact is dissipated by the element of protection made of a hyperdeformable material. The presented methods and applications of the characteristics of hyper elastic materials and composites with the gas phase are used to determine the proper selection of material properties, increasing the opportunities for a proper assessment of the effectiveness of safety devices.

Kyziol and Okninski study dynamics of the Duffing - Van der Pol driven oscillator. Periodic steady-state solutions of the corresponding equation are determined within the Krylov-Bogoliubov-Mitropolsky approach to yield dependence of amplitude on forcing frequency as an implicit function, referred to as resonance curve or amplitude profile. Equations for singular points of resonance curves are solved exactly. Authors investigate metamorphoses of the computed amplitude profiles induced by changes of control parameters near singular points of these curves since qualitative changes of dynamics occur in neighborhoods of singular points. More exactly, conditions for birth of resonances as well as for attractor crises are found. Bifurcation diagrams are estimated to show good agreement with the predictions of theoretical analysis.

An analysis of equations describing single and multi-joint muscles cooperation during movement of limb segments is presented by Zagrodny and Awrejcewicz. The Pareto-optimum problem is considered for the human upper limb in a case of movement in the sagittal plane. Uncertainty of this problem and some additional physiological restrictions are described. Moreover, effects of practical verification based on the video analysis of the volunteer's arm movement and its lack of reproducibility is addressed. Examination of the artificial arm prototype shows similar behavior to the human biological musculo-skeletal system.

Production and construction asymmetry of railway vehicles in the presence of multiple track irregularities on the rail influences the time flow of the wheel. It has an influence on wheel and rail wear defects, especially on driving safety. Production and construction asymmetry is found during the experimental investigation of the basic parameters of mechanical properties of a double-axel freight wagon of Smmps type. The contribution by Nangulo et al. introduces a methodology of analytical solution of the influence of production and construction asymmetry on the vertical dynamic response of a double-axel freight wagon in the presence of multiple track irregularities. Measured field data are used to validate the model.

A non-standard bifurcation, similar to a transcritical one, in a model of a bioreactor is detected by Villa et al. This happens in a periodically-forced system with restrictions on the state space. The bioreactor is periodically fed with substrate. In the mathematical model, a periodic orbit approaches (without hitting) the restriction surface as a bifurcation parameter is varied. The way the orbit approaches the switching surface in the three-dimensional state space is such that it becomes parallel to the restriction surface. This phenomenon is somehow analogous to a transcritical bifurcation, which is described, since another periodic orbit exists inside the restriction surface, but they do not collide.

The objective of the study carried out by Parandyk et al. is to examine a human/mammal circulatory system. Considering structures and operating rules of a natural, biological circulatory system it can be easily stated that it is possible to create an analogous hydromechanical dynamic system. Noting the similarities and taking into account blood and vessels features there is mathematical model given that include differential equations of the fluid mechanics. Additionally a stand/analog consisted of hydraulic and electronics elements is presented. A prototype of the circulatory system is proposed with a construction of the heart as a bicapsular pumping unit powered by external pneumatic system. Solving the equations describing biological system, it gives opportunities to examine some external and internal risk factors, model input signals and activity under different conditions.

Udwadia and Mylapilli expose the connections between the determination of the equations of motion of constrained systems and the problem of tracking control of nonlinear mechanical systems. The new duality between the imposition of constraints on a mechanical system and the trajectory requirements for tracking control is exposed through the use of a simple example. It is shown that given a set of constraints, d'Alembert's principle corresponds to the problem of finding the optimal tracking control of a mechanical system for a specific control cost function that Nature seems to choose. The way Nature seems to handle the tracking control problem of highly nonlinear systems suggests ways in which authors are able to develop new control methods that do not make any approximations and/or linearizations related to the nonlinear system dynamics. More general control costs are used and Nature's approach is thereby extended to general control problems.

Finally, it should be emphasized that the selected papers are mainly oriented toward modeling and identification of mechanical systems. They have been reviewed to satisfy the journal's standards.

In addition, J. Awrejcewicz, a Guest Editor of this Special Issue, greatly appreciates a kind invitation of Professor A.A. Martynyuk to publish the recommended papers. Furthermore, a professional help of the NDST's staff in the final production process is acknowledged.

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