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REVIEW

of the dissertation paper of Valery Christov Covachev
"Systems of differential equations and neural networks with delays and impulses"
submitted for obtaining scientific degree of Doctor of Sciences
in the areas of higher education 4. Natural sciences, mathematics and informatics,
in professional field 4.5. Mathematics, in science speciality
01.01.13 "Mathematical modeling and application of mathematics".

Official opponent (reviewer) Prof. Dr. Phys.-Math. Sci. Allaberen Ashyralyev,
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The presented dissertation consists of a preface and three chapters and is exposed on 286 pages, of which 272 pages basic text, 11 pages a list of 120 titles literature, and the remaining 5 pages are the title pages, contents and index.

The impulsive differential equations are a rather new branch of the theory of ordinary and partial differential equations. They marked their beginning in1960 with the work by V. D. Mil'man and A. D. Myshkis. The investigation of these equations was initially carried out extremely slowly. This was due to the great difficulties caused by the specific properties of the impulsive equations such as "beating" of the solutions, bifurcation, merging of the solutions, dying of the solutions and loss of the property of autonomy.

Despite these difficulties, however, a boom in the development of this theory is observed in the last, say, quarter of a century. The interest in it is caused by the great possibilities of mathematical simulation by means of impulsive differential equations in important fields of science and technology such as the theory of optimal control, theoretical physics, population dynamics, biotechnologies, impulse techniques, industrial robotics, economics, etc.

both the continuous and discrete systems.

differential equations with a small parameter. The development of the theory of impulsive differential equations with a small parameter is connected with the names of V. Lakshmikantham and his collaborators, A.M. Samoilenko, N. A. Perestyuk, A. A. Boichuk and many others in Ukraine, D. D. Bainov and his collaborators in Bulgaria, etc.

Neural network simulations appear to be a recent development. However, this field was established before the advent of computers, and has survived at least one major setback and several eras. Many important advances have been boosted by the use of inexpensive computer emulations. Following an initial period of enthusiasm, the field survived a period of frustration and disrepute. The first artificial neuron was produced in 1943 by the neurophysiologist Warren McCulloch and the logician Walter Pitts.

Neural networks have wide applicability to real world business problems.In fact, they have already been successfully applied in many industries. Since neural networks are best at identifying patterns or trends in data, they are well suited for prediction or forecasting needs including: sales forecasting, industrial process control, customer research, data validation, risk management, target marketing.

Most widely studied and used neural networks can be classified as either continuous or discrete. Recently, there has been a somewhat new category of neural networks which are neither purely continuous-time nor purely discrete-time.This third category of neural networks called impulsive neural networks displays a combination of characteristics of both the continuous and discrete systems.

Thus, the relevance of the themes of dissertation work does not cause any doubt.

The present thesis is based on the author's papers in the last two decades devoted to impulsive differential equations with a small parameter and the global asymptotic stability of equilibrium points and periodic solutions of continuous- and discrete-time neural networks with delays and impulses. It consists of three chapters.

Chapter 1 has an auxiliary character. It contains the necessary information about impulsive differential equations, periodic solutions of linear impulsive systems in the noncritical and critical cases, almost periodic solutions of linear impulsive systems, and differential equations with a deviating argument.

Chapter 2 deals mostly with periodic and almost periodic solutions of impulsive systems with delay. The role of a small parameter is played by the delay, or the amplitude of the oscillation of the delay about a constant value.

In §2.1 sufficient conditions for the existence of a periodic solution of a periodic retarded or neutral system in a neighbourhood of an isolated periodic solution of the system without delay are obtained.

In §2.2 a system with impulses and a small delay such that the corresponding system without delay is linear and has a family of periodic solutions is studied. More generally, a boundary value problem for an impulsive differential system with many small delays such that the corresponding system without delay is linear and the boundary value problem for the homogeneous system has a family of nontrivial solutions is investigated.

constant by a small-amplitude periodic perturbation, provided that the corresponding system without delay has an isolated ω–periodic solution are investigated. If the period of the small-amplitude perturbation of the delay is (a rational multiple of) ω, sufficient conditions for the existence of a periodic solution are obtained; if it is rationally independent with ω, sufficient conditions for the existence of an almost periodic solution are obtained.

Chapter 3 begins with some general information about neural networks and it is concerned with the global asymptotic (in most cases, exponential) stability of equilibrium points and periodic solutions of continuous- and discrete-time neural networks with delays and impulses.

In §3.1 sufficient conditions for the global exponential stability of unique equilibrium points of continuous-time neural networks are obtained.

In §3.2 discrete-time analogues of continuous-time neural networks and sufficient conditions for the global exponential stability of their unique equilibrium points or periodic solutions are obtained.

Finally, in §3.3 sufficient conditions for global asymptotic stability of the unique equilibrium point of a continuous-time Cohen-Grossberg neural network of neutral type and its discrete-time counterpart provided with impulse conditions are obtained.

Thus, even a summary of the results is a clear evidence of that together they can be qualified as new scientific progress in the theory of differential equations and its application analysis. The thesis contains a number of new techniques and ideas proposed by the author. I also note that the work is done by V. Covachev on his own, his name corresponds to the content, the main results will be found applicable in applied mathematics and computational mathematics . They will be useful for professional mathematicians as well as for students in the fields of ordinary and partial differential equations and applied mathematics in Technical University Sofia, Institute of Mathematics of Bulgarian Academy of Sciences, Fatih University, Istanbul, College of Science, Sultan Qaboos University, Sultanate of Oman.

The main results of the author in the thesis are 39 published papers in international journals and conference proceedings including 19 international ISI journal publications. In the dissertation are included results of the author joint papers with his colleagues.

Valery Covachev's citation index is over 178. His h-index is 4. His average citations per item are 8.48. Among these, there are publications in some prestigious mathematical journals like Journal of Mathematical Analysis and Applications, Abstract and Applied Analysis, Applied Mathematics and Computation, Dynamic Systems and Applications, Journal of Physics A: Mathematical and General, Fluctuation and Noise Letters, Proceedings of the American Mathematical Society, Доклади на Българската академия на науките.

The work is framed very carefully, there are very few typos. Here I should add a few critical remarks. In Chapter Two there are no examples given. In Chapter Three there are a few examples (in §§3.1.2, 3.1.3, 3.2.3, 3.3.1 and 3.3.2). They do not go further than verifying the assumptions of the respective theorems, finding the equilibrium point (if distinct from 0) and evaluating the Lyapunov exponent (in the case of exponential

numerical computations or graphs of solutions. These flaws do not affect the accuracy of the results and do not spoil the logical whole, beautifully written work.

The author's abstract correctly reflects the contents of the dissertation.

Moreover, Valery Covachev's contribution to science and technology within Bulgaria has been tremendous which could be gauged from his active participation in a number of national research and academic organizations. Furthermore, his contribution in science and technology at the international level is equally remarkable
which is evident from his current joint research with scientists in different countries.

I think that the dissertation paper of Valery Christov Covachev "Systems of differential equations and neural networks with delays and impulses" meets all the requirements of the doctor dissertations claim according to the "Regulations on the procedure for the award of degrees," and its author Valery Christov Covachev deserves awarding scientific degree of doctor of sciences, in the areas of higher education 4. Natural sciences, mathematics and informatics, in professional field 4.5. Mathematics, in science speciality 01.01.13 "Mathematical modeling and application of mathematics".

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