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Preface

The present collection of papers is devoted to the problem of synchronization of nonlinear processes in dynamical systems of different nature and the degree of complexity. Synchronization is one of the typical and important phenomena in nature and in the theory of dynamical systems. It manifests itself in the adjustment of certain relationships between characteristic time scales, frequencies and phases of two and more interacting oscillators. The effect of synchronization leads to the increase of order degree of oscillations and can often be considered as the main reason for the appearance of spatio-temporal structures. In this sense synchronization can be treated as one of the manifestations of self-organization in nonlinear dissipative systems.

Synchronization of oscillations was first observed by Huygens more than 300 years ago. But only recently this problem has attracted much attention due to elaboration and development of electronic communications aids. The Van der Pol oscillator served as an example for creating the theory of periodic oscillations synchronization, having become classical.

Synchronization of periodic oscillations is observed if the oscillations of the system occur with a constant and rational winding number $\Theta = m:n$ which holds in a finite region of system's parameters. The latter is called the synchronization region. Inside such a zone the effects of frequency and phase locking take place. The frequency locking means that two initially independent frequencies become rationally connected, i.e. $\omega_1 : \omega_2 = m:n$. When the phase is locked, the phase difference of oscillations is constant in time, i.e. $|n\Phi_1(t) - m\Phi_2(t)| = \text{const}$.

From the physical point of view, two types of synchronization are distinguished, namely, forced and mutual synchronization which reflect the ways of how oscillators interact. In the mathematical treatment of this problem, in the regime of both forced and mutual synchronization the system should possess a stable limit cycle. For the case of weak interaction this cycle represents a resonance cycle on a two-dimensional torus. Synchronization is observed if the resonance cycle on the torus is stable and consequently, the winding number has a rational value. The loss of synchronization occurs through a saddle-node bifurcation of the resonance cycle. The effects of frequency and phase locking correspond to the stable resonance cycle.

For strong interaction between oscillators the resonance torus no longer exists but a synchronous limit cycle is retained stable inside the synchronization region. In this case synchronization is destroyed through the loss of stability by the cycle followed by a torus birth (Neimark's bifurcation).

Two bifurcation conditions mentioned above determine two different mechanisms of synchronization, namely, frequency (phase) locking and suppression of one of the independent frequencies.

Recent developments of nonlinear dynamics have led to a generalization of the classical knowledge on synchronization to systems with chaotic and stochastic oscillations. As applied to chaotic oscillations, several different concepts of synchronization, namely, full synchronization, phase synchronization and so-called generalized synchronization, have been revealed and studied. The concept of phase synchronization has appeared to be most fruitful. It consists in locking of the instantaneous phases of oscillations and does not involve relations between the instantaneous amplitudes of the interacting oscillators. This fact allows one to explore synchronization of both chaotic and stochastic oscillations which are characterized by a continuous power spectrum. In particular, it has been found that noise can play the constructive role optimizing the synchronization process in bistable systems.

Nowadays, the processes of synchronization are extensively studied in extended systems and their models. Extended systems, being very complicated, can demonstrate a great variety of phenomena caused by synchronization. Many new interesting effects can be expected in this direction, which will enrich our knowledge on evolutional processes of living and nonliving matter.

Undoubtedly, in the frame of a single issue it is impossible to fully reflect a wide range of problems concerning synchronization of oscillatory and wave processes. The papers collected in this issue represent only their small part. Two special issues of the *Journal of Bifurcation and Chaos* (edited by Prof. R. Chen and Prof. J. Kurths), which are also devoted to the problem of synchronization, will appear this year. In this connection one may assume that three special issues based on the studies of synchronization of nonlinear oscillations and waves will provide the possibility to present in more detail modern results in this scientific field.

In conclusion, on hehalf of the Editorial Board of *Discrete Dynamics in Nature and Society* I would like to thank all the authors for submitting their papers to this issue and wish them success in their further scientific research.

V. Anishchenko

Mathematical Problems in Engineering

Special Issue on
Modeling Experimental Nonlinear Dynamics and Chaotic Scenarios

Call for Papers

Thinking about nonlinearity in engineering areas, up to the 70s, was focused on intentionally built nonlinear parts in order to improve the operational characteristics of a device or system. Keying, saturation, hysteretic phenomena, and dead zones were added to existing devices increasing their behavior diversity and precision. In this context, an intrinsic nonlinearity was treated just as a linear approximation, around equilibrium points.

Inspired on the rediscovering of the richness of nonlinear and chaotic phenomena, engineers started using analytical tools from "Qualitative Theory of Differential Equations," allowing more precise analysis and synthesis, in order to produce new vital products and services. Bifurcation theory, dynamical systems and chaos started to be part of the mandatory set of tools for design engineers.

This proposed special edition of the *Mathematical Problems in Engineering* aims to provide a picture of the importance of the bifurcation theory, relating it with nonlinear and chaotic dynamics for natural and engineered systems. Ideas of how this dynamics can be captured through precisely tailored real and numerical experiments and understanding by the combination of specific tools that associate dynamical system theory and geometric tools in a very clever, sophisticated, and at the same time simple and unique analytical environment are the subject of this issue, allowing new methods to design high-precision devices and equipment.

Authors should follow the Mathematical Problems in Engineering manuscript format described at http://www.hindawi.com/journals/mpe/. Prospective authors should submit an electronic copy of their complete manuscript through the journal Manuscript Tracking System at http://mts.hindawi.com/ according to the following timetable:

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