Stability analysis and synchronization of coupled dynamical systems with application to natural science

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Abstract. One aspect of coupled dynamical systems which received great attention is synchronization. This phenomenon occurs very often in nature and has many applications in biology, physics and engineering. Maybe one of the earliest studies of synchronous motion was due to Huygens in 1673. In physics, in the study of coupled nonlinear oscillators, great impact was made by the work of Kuramoto. An example in the field of system control is the work in coordination and control of group of robots, vehicles and mechanical systems. Another interesting example arises when studying emergent collective behavior (swarming) in some large groups of organisms like bacteria, ants, birds etc. Of special interest are the models of pulse-coupled biological oscillators where the oscillators communicate by sudden impulses, as in the case of neurons. An example is the Peskin's model of cardiac pacemaker cells - under some assumptions it was shown that the cells mutually synchronize and fire together no matter from which state they have started. This model was later used for study of a model of coupled neurons. We are interested in the properties of these natural phenomena. In order to better describe them, we use models of coupled dynamical systems. We analyze the collective dynamics of these systems, which are represented by stochastic differential equations. The emphasis on our research is on stability analysis and synchronization of coupled neural networks. The aim of this paper is to give an overview of the results and problems in the current research on this topic.

Keywords: Stability Analysis · Synchronization · Coupled Dynamical Systems · Coupled Oscillators · Stochastic Differential Equations · Neural Networks.