Synchronization of electronic Hindmarsh-Rose neurons

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Synchronization is the phenomena where coupled dynamical systems adjust their motion due to some (weak) interaction such that the systems show, after some time, identical motion independent of their starting positions. Synchronous behavior of systems is witnessed in a vast number of research area’s. Beautiful examples are, for instance, the simultaneous flashing of male fireflies on bank along rivers in Malaysia, Thailand and New Guinea, and the synchronous release of action potentials in parts of the mammalian brain. In the field of mechanical engineering synchronization can be found when, for example, robots do have to cooperate. One can also think of surgery robots where a robot (slave) follows the movements of the hands of a surgeon (master).

It is important to understand the mechanisms behind the synchronized motion of systems, i.e. under which conditions do these systems synchronize. Here we restrict ourselves to the synchronization of diffusively coupled systems; that is all systems are mutually coupled using linear functions of the outputs of the systems. Using a semi-passivity based approach [2] we can derive conditions that guarantee the existence of synchronized regimes. These regimes might correspond to the full synchronized state, i.e. all systems have identical motion, as well as to partial synchronization where the only some systems do synchronize.

We present the synchronization of diffusively coupled Hindmarsh-Rose (HR) electronic neurons. The HR model [1] is a well-known model in the field of neuroscience that provides a description of the action potential generation in neuronal cells. This model consists of three coupled nonlinear differential equations and is capable of producing both simple and complex oscillatory motion. The electronic neurons are analog electrical circuits which integrate the three differential equations of the HR model. An experimental setup consisting of maximal four circuits, operating in the chaotic bursting regime, is used to show the existence of partial or full synchronized states.

References