Pinning control of an array of the globally coupled FitzHugh–Nagumo oscillators via a single damaged unit

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Abstract. A combined control method for stabilizing the steady states of the globally coupled oscillators is described. It includes two techniques, the pinning control and damaging a single oscillator. Two versions of damaging the pinned oscillator are considered: (1) the oscillator is short-circuited with an external adjustable voltage source, (2) the oscillator is short-circuited with an external large capacitor. Analytical, numerical and experimental investigations have been carried out using an array of the mean-field coupled FitzHugh–Nagumo oscillators.

Introduction

Coupling of oscillators leads to their synchronous behaviour, i.e. to oscillation at the same frequency and with constant (not necessarily zero) phase differences [1]. Synchronization sometimes is an undesirable phenomenon, e.g. strong synchrony of neurons in human brain, where it causes the symptoms of the Parkinson's disease [2]. There are two main ways to avoid synchronization. The first one is to apply some sophisticated feedback, destroying synchronous states (see, for example, [2, 3, 4] and references therein). The second one is a straightforward feedback method, which stabilizes the unstable steady states of the oscillators [5]. A related (non-feedback) technique is the medically approved deep brain stimulation (DBS), applied to patients with the Parkinson's disease, using high frequency periodic pulses. The mechanism of the DBS is not fully understood. It is supposed that high frequency periodic forcing inhibits the spiking neural oscillators by means of stabilizing (on the average per period) their steady states [6]. In a recent paper we described a pinning technique, where stabilization of an array of the coupled neural type FitzHugh–Nagumo (FHN) oscillators is achieved via a single unit by means of stabilizing its steady state [7]. In the present paper, we suggest to stabilize an array of the FHN oscillators by means of *damaging* a single accidentally accessed or randomly chosen unit (Fig. 1). We note, that it is much simpler to damage an oscillator, than to dynamically stabilize its steady state.

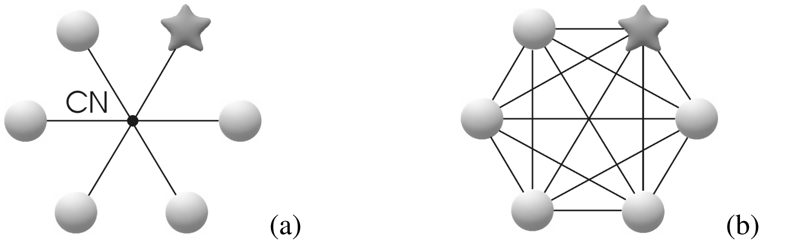

Figure 1: Globally coupled oscillators. (a) Coupling via common node. (b) All-to-all coupling. Dark gray stars are damaged oscillators.

Results and discussion

Two ways of damaging the pinned oscillator have been considered. The first and the simplest one is short-circuiting the oscillator by means of an external voltage source. The external voltage should be carefully adjusted to match the internal voltage of the unit(s) in order to avoid harmful DC currents. Mathematically it corresponds to replacing the fast variable of the pinned oscillator with a constant adjustable reference. The second way is an adaptive one. It is implemented by means of short-circuiting the pinned oscillator with an external large capacitor. In this case the problem of the DC currents is automatically removed. Moreover, there is no need to adjust the controller. Mathematically this technique is described by replacing the fast variable of the pinned oscillator with a slow variable voltage across the external capacitor. The control method has been investigated (a) analytically using the mean-field approximation [5] and low-degree (the 2nd- and the 3rd-degree) characteristic equations, (b) numerically by direct integrating the set of differential equations, and (c) experimentally employing a dedicated electrical circuit that imitates the dynamical behaviour of an array of the globally coupled FHN oscillators [4, 5, 7]. The results show that above some critical value of the coupling strength between the oscillators the entire array is fully controlled, namely the steady states of the all oscillators are stabilized. The control method exhibits good robustness against external interference.

References

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