Title	Chaotic Itinerancy in Gap Junction-Coupled Class I* Neurons
Author(s)	Tadokoro, Satoru; Yamaguti, Yutaka; Tsuda, Ichiro; Fujii, Hiroshi
Citation	The 8th RIES-Hokudai International Symposium on "微"[bi], 112-113
Issue Date	2006
Doc URL	http://hdl.handle.net/2115/29713
Type	proceedings (author version)
File Information	8RIES112.pdf

Chaotic Itinerancy in Gap Junction-Coupled Class I* Neurons

Satoru Tadokoro[1], Yutaka Yamaguti[1], Ichiro Tsuda[2, 1], and Hiroshi Fujii[3]
[1]Department of Mathematics, Graduate School of Science,
Hokkaido University, Sapporo 060-0810, Japan
[2]Laboratory of Computational Life Science, Research Institute of Electronic Science,
Hokkaido University, Sapporo 060-0812, Japan
[3]Department of Information and Communication Sciences,
Kyoto Sangyo University, Kyoto 603-8555, Japan

Gap junctions (GJs), i.e. electric coupling among certain kinds of interneurons such as fast-spiking(FS) and low-threshold spiking (LTS) neurons have been discovered to exist in the mammalian neocortex. They are not only ubiquitous but also massive[1, 2)]. Although it is generally believed that the GJ-coupling among interneurons promotes their synchronous firing[1, 2)], less is known about the nature of collective behaviors of these interneurons coupled by GJs in a massive way.

We investigate dynamical behaviors of the GJ-coupled network of interneurons and its bifurcation structure by numerical simulation studies. We adopt a simple class I* neuron model as the interneuron. Neurons are classified into two classes called class I and class II. A neuron of class I starts firing with the zero (i.e., arbitrarily low) frequency when the applied current reaches its threshold and then shows an increasing firing frequency as the current increases. The firing frequency of the class I neuron varies widely with changes in the strength of the current. In contrast, a neuron of class II starts firing with a nonzero frequency as the current exceeds its threshold and produces only a modest increase in the firing frequency with increasing the current. Several models of the interneuron seem to be in good agreement with the above notion of the class I. Thus it is reasonable to adopt a class I neuron model as a model of the interneuron. The class I* is a subclass of the class I.

We have found that GJ-coupled networks of class I* neurons exhibit transitory behaviors in which spontaneous and irregular transitions among various dynamic states, e.g., synchronized states or chaotic states, occur. Such transitory behaviors appear in rather wide range of parameter values in a boundary region between ordered and turbulent phases. Among the transitory behaviors, we focus the dynamic behavior consisting of an alternation of characteristic spatio-temporal patterns: the all-synchronized state, metachronal waves, a weakly chaotic state, and turbulence. Here the metachronal wave means a wave with orderly phase shifts of neurons' activity. Fig.1 shows the Poincare map of this behaviors (center) and spatio-temporal patterns of its dynamic components.

One can see an ordered structure associated with randomly scattered points on the Poincare section. The former represents an attractor ruin and the latter scattered points represent strong chaos. The behavior shown in Fig.1 can be interpreted as chaotic itinerancy[3]. It is expected to be a possible mechanism of the non-stationary and transitory phenomena observed experimentally in the mammalian neocortex[4].

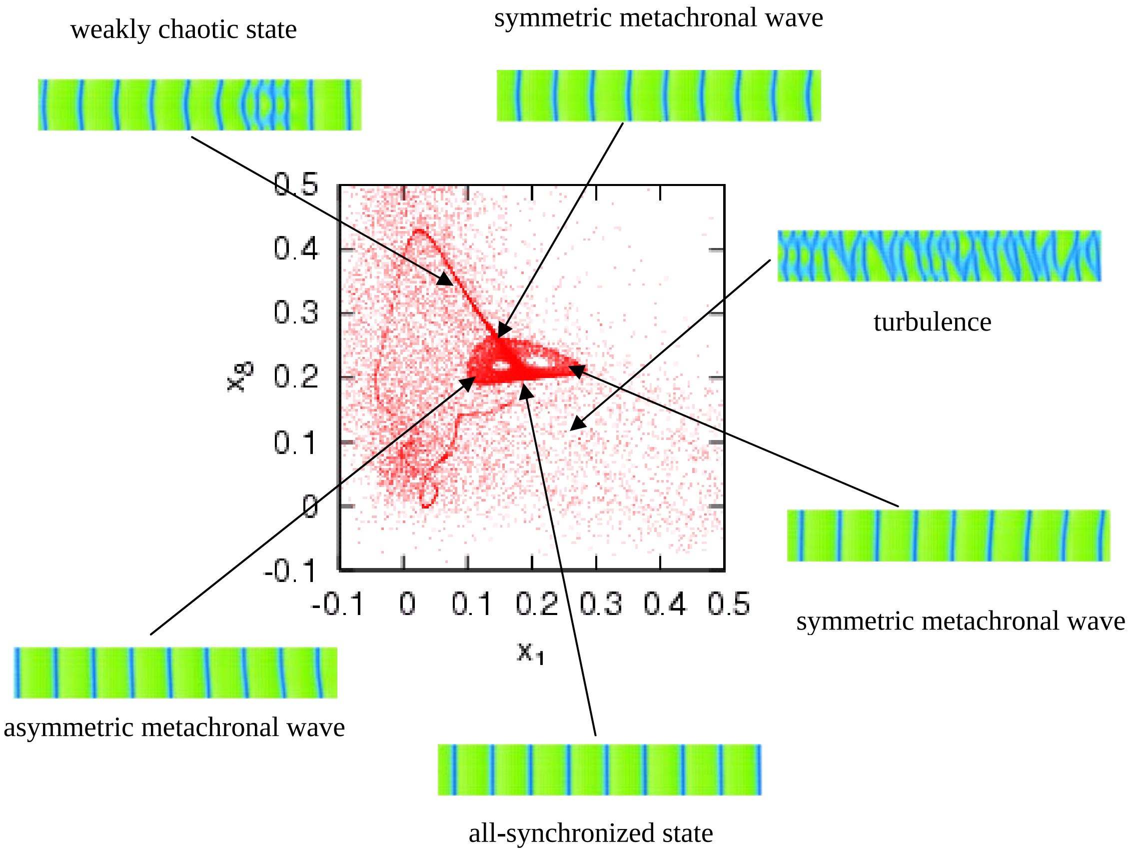

Fig.1. Spatio-temporal patterns of the chaotic itinerant behavior and its Poincare map in the case of 16 neurons. We choose the hyper-plane on which the average of neurons' membrane potentials equals to 0.2 as the Poincare section. The projection to the (x_1, x_8) plane of the Poincare section is shown. A variable x_i represents the membrane potential of the i-th neuron. Points $(x_1, x_8) = (0.2, 0.2)$ and (x_1, x_8)~(0.15, 0.25) on the section correspond to the all-synchronized state and the symmetric metachronal state, respectively.

1) M. Galarreta and S. Hestrin, Nature 402, 72-75 (1999).

2) J. R. Gibson, M. Beierlein, and B. W. Connors, Nature 402, 75-79 (1999).

3) I. Tsuda, H. Fujii, S. Tadokoro, T. Yasuoka, and Y. Yamaguti,
J. of Integrative Neuroscience 3 159-182 (2004)

4) C. M. Gray et. al., Visual Neurosci. 8, 337-347 (1992)