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BIFURCATION-BASED MODEL CONSTRUCTION OF A PYRAMIDAL CELL OF THE PRIMARY VISUAL CORTEX

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Abstract. *Many mathematical models of different neurons have been proposed. However, the way of modeling the regulation of calcium ions (Ca^{2+}) has not been established yet. Therefore, we try to construct a physiologically plausible pyramidal cell model of the primary visual cortex which contains many regulating systems of the intracellular Ca^{2+} concentration [Ca^{2+}]. In this paper, we demonstrate the usefulness of the nonlinear dynamical system theory such as global bifurcation and slow/fast decomposition analyses for a construction of the neuron model.*
Keywords: Primary visual cortex, Pyramidal cell, Hodgkin-Huxley-type equations, Bifurcation structure

1. **Introduction.** Complicated information processing of brain is performed by the electrical activity of neurons. Neurons transmit each other an electrical signal called action potential for the information processing. The action potential is a spiking or bursting and plays an important role in the information processing of the brain.

In the visual system, visual signals from the retina are processed by neurons in the primary visual cortex. There are several types of neurons in the visual cortex, and pyramidal cells compose roughly 80% of the neurons of the cortex [1, 2]. Pyramidal cells are connected each other and form a complex neuronal circuit. The fundamental structure of the circuit is roughly understood by the previous physiological and anatomical studies [3]. However, it is not completely understood how visual signals propagate and function in the neuronal circuit of the visual cortex. In order to investigate the neuronal circuit, not only physiological experiments but also simulations by using a mathematical model of neuron are important.

Many mathematical models of neurons have been proposed so far [4]. Though there are various models of neurons, the way of modeling the regulating system of the intracellular calcium ions (Ca^{2+}) has not been established yet. The regulating system of the intracellular Ca^{2+} is a very important element because the intracellular Ca^{2+} plays crucial roles in cellular processes such as hormone and neurotransmitter release, gene transcription, and regulations of synaptic plasticity. Therefore, it is important to establish the way of modeling the regulating system of the intracellular Ca^{2+}.

In this paper, we try to construct a model of pyramidal cells by regarding previous physiological experimental data, especially focusing on the regulating systems of the intracellular Ca^{2+} such as Ca^{2+} buffering, Na^+/Ca^{2+} exchanger and Ca^{2+} pump current. In order to estimate the value of parameters which cannot be determined by physiological