

DOCTORAL THESIS

Adaptive networks and synaptic plasticity in neural systems: interplay between structure and dynamics

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**Adaptive Networks and Synaptic
Plasticity in Neural Systems
— Interplay between Structure
and Dynamics**

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A thesis submitted in partial fulfillment of the requirements
for the degree of
Doctor of Philosophy

Principal Supervisor: Prof. ZHOU Changsong

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Abstract

Research in this thesis is presented from general adaptive networks to neural networks with synaptic plasticity. Although the emphasis is on neural networks, we firstly study a general adaptive network by introducing a weight-adaptation scheme motivated from Hebbian learning rule in neural systems. The modeling results show that the adaptive network can self-organize into modular structure with dynamical clusterings. Moreover, the adaptation scheme can amplify community structure by the resulting dynamical clusterings. Inspired by these results, a biophysically detailed form of Hebbian synaptic plasticity, spike-timing-dependent plasticity (STDP), is secondly studied in neural system. We construct a two-dimensional spatial neural network model with STDP and use external currents to stimulate alternately on different spatial layers in the model. It's found that, STDP can induce a feedforward structure (this can be regarded as the organization with unidirectional connections between communities) by stimulus-dependent dynamical clusterings. The resulting feedforward structure and the propagative dynamics on the network structure can reflect the underlying property of STDP. Thirdly, in a feedforward neural network model, we investigate the role of another important type of synaptic plasticity, short-term depression (STD), in visual information processing. The model can provide a possible explanation for the role of microsaccades (small eye movements) in counteracting visual fading during fixation. Moreover, the model reproduces several experimental observations and gives some significant predictions. Finally, we further study the role of STD in the neural response to microsaccades by considering simultaneously STD and retinal adaptation. It's found that, STD contributes to sharp response to microsaccades, consisting with experimental finding. Furthermore, STD enhances effectiveness and sensitivity of neural response to microsaccade-induced spatiotemporal changes. Taken together, these results of the thesis further demonstrate that, the interplay between neural dynamics and synaptic plasticity plays an important role in neural information processing. The work presented in this thesis serves as a foundation for further investigation in the future.

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