Artificial retinal and its application in retinal physiology

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The retina is a part of the central nervous systems which are complex and massive parallel neuronal circuits. In order to elucidate the functional structures of retinal circuit, simulation studies based on models inferred from physiological experiments (physiological models) play an essential role. However, physiological experiments can be conducted only under restricted conditions because of technical problems. Namely, responses of a limited number of neurons to simplified images, e.g. a bar or a spot of light, have been recorded in isolated retinas or in immobilized animal under anesthesia. In real world, however, the retinal circuit conducts real time computations under natural visual environment, where the retina is continuously exposed to images composed of complex features under eye movements. In this situation, it is not clear if the functional structures of the retinal circuit can be identified with simulation studies employing the physiological models inferred in unnatural visual environments.

Our goal is to design a hardware system that implements essential circuit structures of the retinal circuit to study spatio-temporal properties of retinal cell responses under more realistic visual environments. The system that is referred to as artificial retina, consists of a neuromorphic analog very large scale integrated (VLSI) circuit sensor, an FPGA circuit and a digital computer. While the VLSI sensor carries out the spatial filtering on input images instantaneously, using built-in resistive networks that emulate the receptive field of neuronal syncytium, the digital parts carry out the temporal filtering to reproduce the dynamical properties of retinal cell responses. The system also can deal with some kinds of nonlinear properties, such as synaptic delay, rectifications and a logarithmic input-output relation. The computation of the neural images, including 128 × 128 pixels, are carried out at a frame rate of 200 Hz, which is high enough to cover the frequency components of photoreceptor response. We conducted real time simulations of neural images using the artificial retina for natural scenes. The proposed simulation system is expected to aid in understanding the visual computation in the retina.