Live Demonstration: Video-to-Spike Conversion Using a Real-Time Retina Cell Network Simulator

Seungbum Baek[1], Jason K. Eshraghian[1], Wesley Thio, Yulia Sandamirskaya, Herbert H.C. Iu and Wei D. Lu
[1]*These authors contributed equally to the live demo.*

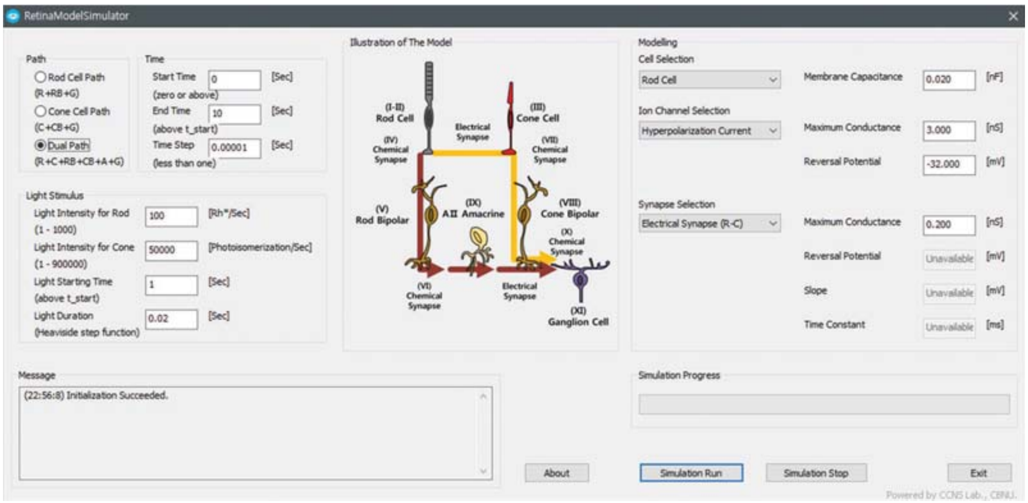

Fig. 1: Execution screen of the simulator. User-inputs are configurable on the fly, including the type of photoreceptor stimulated, cell parameters, ion channel parameters, and synapse parameters.

***Abstract*—Our live demonstration will present a discrete neuronal network simulator of the vertebrate retina, using a collation of prominent single-compartment outer segment neurons and morphologically accurate inner segment neurons. Cascaded models are scarce in literature due to computational intensity, but we successfully produce a biophysically accurate simulator that converts an input stream of pixels at 25-30 fps into a system of graded and spiking membrane potentials in real-time. We hope the simulator better facilitates an understanding of how retina cells represent visual information, and also provide an intuitive manner for neuroscientists to generate responses to video input for improved neural encoding schemes.**

Motivation: The constituent cells that make up the retina, and their connectivity is, at this stage well understood. What remains to be clear is the precise nature in which computation and filtering takes place, and why evolution has dictated that this particular structure is the most efficient mode of representation of visual information. Understanding these problems requires biophysically accurate datasets, in favor of discrete spike events that is more commonly used in behavioral and functional models of neural encoding. The barrier to developing accessible and real-time video-to-spike converters that mechanistically describe the responses of all cell types in the vertebrate retina is due to the computational intensity involved with discrete neuronal network models. These types of cascaded models are simultaneously solving hundreds of nonlinear ordinary differential equations (272 in our case), and are challenging to operate in real-time. We achieve real-time performance of such a model by optimizing the numerical methods used. The detailed model, simulator description, CPU utilization, and numerical methods employed to optimize the simulator are based on the results in [1]–[3].

Simulator: The simulator was designed for a Windows OS in the C language. The GUI is written in Microsoft Foundation Class, and the graphs are displayed in real-time using the Kst graph plotting tool. Interfacing with a front-end camera is achieved using the OpenCV library. The simulator interface is shown in Fig. 1. Model parameters are available in an online appendix provided in [3].

Demo Setup: The demo will use a camera connected via USB to a laptop which will be locally running the simulator. A specification of our simulator is the ability to run in real-time without the need for high-performance GPUs or CPUs, or cloud-access. The user experience involves the participant operating the camera orientation, position, and aperture. The simulator will convert what the camera captures into a population of cell responses that are graphically generated in real-time. A range of neutral density filters will be available for the user to further modulate exposure, and show how varying input light intensity will affect the response of all retina cells involved in the image processing task. The spike train can be stored and sent to the user as a memento of the demo, depicting the retina's interpretation of the participant's facial features in the form of physiological signals. The simulator has been made accessible for use and for modification at the following link: https://github.com/sbbaek-cbnu/artificial_retina_simulator_github.

References:

[1] K. Cho, *et al.*, "Signal flow platform for mapping and simulation of vertebrate retina for sensor systems", *IEEE Sensors J.*, **16**(15), 2016.

[2] J. K. Eshraghian, *et al.*, "Formulation and implementation of nonlinear integral equations to model neural dynamics within the vertebrate retina", *Int. J. Neural Syst.*, **28**(7), 2018.

[3] J. K. Eshraghian, *et al.*, "A real-time retinomorphic simulator using a conductance-based discrete neuronal network", *2020 IEEE Int. Conf. Artificial Intelligence Circuits and Syst.*, *in press*, 2020.