Multimodal Spike Coding for Memcapacitive Neuromorphic System

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Neuromorphic systems have been investigated to accelerate machine learning calculations and reduce power dissipation by hardware architecture of spiking neural networks (SNN), which is more similar to biological brains in comparison with artificial neural networks (ANN). Conventional rate coding in the SNNs, which utilizes the spike frequency to represent signals, is highly compatible with analog operation in the ANNs, and the technology developed recently can be employed. However, the rate coding needs many spikes and has problems of long latency and large power dissipation, and the research is active for a more efficient coding method. In this presentation, we introduce a novel coding scheme, multimodal spike coding, which utilizes not only the spike frequency but also their voltage amplitude and time width, which have not been utilized in the conventional SNNs. It is expected by the multimodal spike coding that the amount of information transmitted per spike increases than the conventional rate coding. Moreover, we adopt memcapacitors and charge pump circuits for synapse elements, which realize a voltage-domain synaptic operation consuming less power during switching than the current-domain one by memristors. We have performed elementary analysis for the proposed ideas on neuron and synapse circuits by the device and circuit models and simulators supported by VLSI Design and Education Center (VDEC), the University of Tokyo with the collaboration with SYNOPSYS Corporation for the use of HSPICE. It was exhibited that the proposed ideas can successfully demonstrate SNN working.

[1] R. Oshio, et al., CANDAR 2021, 114 (2021).

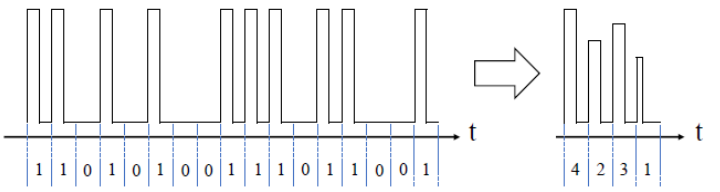

Fig. 1. Spike coding

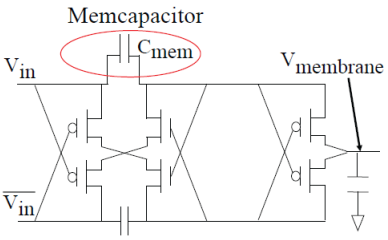

Fig. 2. Synapse element

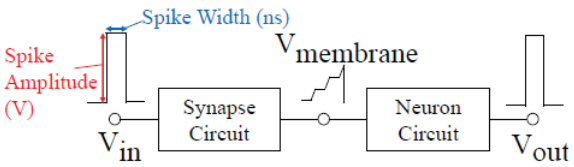

Fig. 3. Simulation circuit

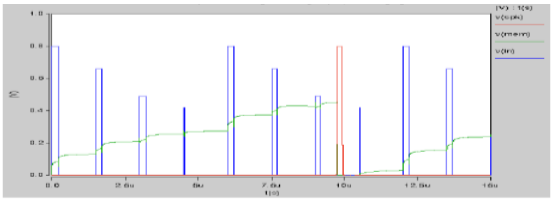

Fig. 4. Simulation result