Axonal and dendritic delays enable competitive SNNs for keyword classification

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Training delays has been shown to improve the performance of spiking neural networks (SNNs) on temporally complex tasks. However, these gains have so far been demonstrated only with synaptic or recurrent delays, both of which introduce substantial computational and memory overhead. We investigate whether simpler architectures based on standard leaky integrate-and-fire (LIF) neurons can achieve competitive performance by learning axonal or dendritic delays [1]. The results show that this approach is sufficient to match or exceed prior methods on challenging speech benchmarks, reaching 95.58% accuracy on Google Speech Commands (GSC) and 80.97% on Spiking Speech Commands (SSC), while reducing both memory usage and computational cost. Axonal delays provide the most favorable trade-off, offering lower buffering requirements and slightly higher accuracy than dendritic delays. Moreover, performance remains largely preserved under strong delay sparsity, with as few as 20% of delays active, indicating that efficient temporal representations can be maintained with significantly reduced resource usage. Additional experiments also show that tuning delay parameters improves synaptic delay baselines, reinforcing the comparison and highlighting learnable delays as an effective and resource-efficient mechanism for temporal processing in SNNs.

Complementing this algorithmic contribution, we implemented an SNN network with axonal delays on an FPGA-based event-driven accelerator [2]. Leveraging the sparse and low-latency nature of spike-based computation, the proposed design integrates delay mechanisms while maintaining low computational cost and hardware overhead. The system is evaluated on Spiking Heidelberg Digits (SHD) and Spiking Speech Commands (SSC), where 500 randomly sampled test inputs are streamed to the FPGA. The accelerator achieves 94.6% accuracy on SHD and 65.6% on SSC, demonstrating competitive performance with low parameter counts and minimal additional resource utilization, particularly in memory. Together, these results show that axonal delays not only improve SNN performance but can also be implemented efficiently in practical neuromorphic hardware systems.

[1] Y. Bouhadjar, and E. Neftci. Sparse Axonal and Dendritic Delays Enable Competitive SNNs for Keyword Classification. arXiv preprint arXiv:2602.09746. 2026.

[2] Y. Zhao et al. Efficient FPGA Implementation of Spiking Neural Networks with Integrated Axonal Delays. IEEE BioCAS (pp. 562-566). 2025.