Distilling Spikes: Knowledge Distillation in Spiking Neural Networks

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Abstract

- Spiking Neural Networks (SNN) are energy-efficient computing architectures that exchange spikes for processing information, unlike classical Artificial Neural Networks (ANN). SNNs are better suited for real-life deployments and benefit from deeper architectures to obtain improved performance.

- The memory, compute and power requirements of SNNs also increase with model size, and model compression becomes a necessity. Knowledge distillation is a model compression technique that enables transferring the learning of a large machine learning model to a smaller model with minimal loss in performance.

Training Methodology

1. We first train a teacher SNN which is then used in Knowledge Distillation for a student network.
2. Given an input image, the weights of teacher SNN are frozen while the student SNN is trained.
3. The KD process involves training of this two-stream setup with the proposed loss functions on the post-synaptic spike patterns of the Teacher and Student SNN models.

Loss Function

- The 3-D tensor (time x classes x mini-batch size) is referred as spiking activation tensor (SAT)
- Losses are calculated by comparing the SATs of both teacher and student model
- \( L_{KL} \), \( L_{L1} \), \( L_{L2} \) loss computed on entire tensors and sliding window losses for \( L_{L1} \), \( L_{L2} \)

\[
L_{KL} = \sum_{k} \sum_{j} \sum_{t} |S_{T}[i \cdot i + \Delta; j; k] - S_{S}[i \cdot i + \Delta; j; k]|_{m}
\]

Results

- We demonstrate distilling knowledge from a large SNN model trained for image classification
- Multistep distillation strategy offers further improvement in performance by using an intermediate TA network

Conclusion

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Fig: Working of a Spiking Neuron

Our Contribution

- We propose techniques for knowledge distillation in spiking neural networks for the task of image classification. We present ways to distill spikes from a larger SNN, also called the teacher network, to a smaller one, also called the student network
- We demonstrate the effectiveness of the proposed method with detailed experiments on three standard datasets while proposing novel distillation methodologies and loss functions
- We also present a multi-stage knowledge distillation technique for SNNs using an intermediate network to obtain higher performance from the student network
- Our approach is expected to open up new avenues for deploying high performing large SNN models on resource-constrained hardware platforms

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