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High-Fidelity ANN-to-SNN Conversion via Closed-Loop CKA Distillation

Bozhou Li, Chubo Liu, Yan Ding, Yufeng Zhang, Zhuo Tang, Kenli Li

Hunan University · The Ministry of Education Key Laboratory of Fusion Computing of Supercomputing and Artificial Intelligence

One-line claim

A source-preserving closed-loop refinement framework repairs conversion errors after ANN-to-SNN mapping, enabling low-latency SNNs with high fidelity.

Core mechanism

Freeze the source ANN, convert once, then fine-tune the SNN with global output distillation and adaptive local CKA feature alignment.

PROBLEM

Open-loop conversion creates a fidelity-latency trade-off

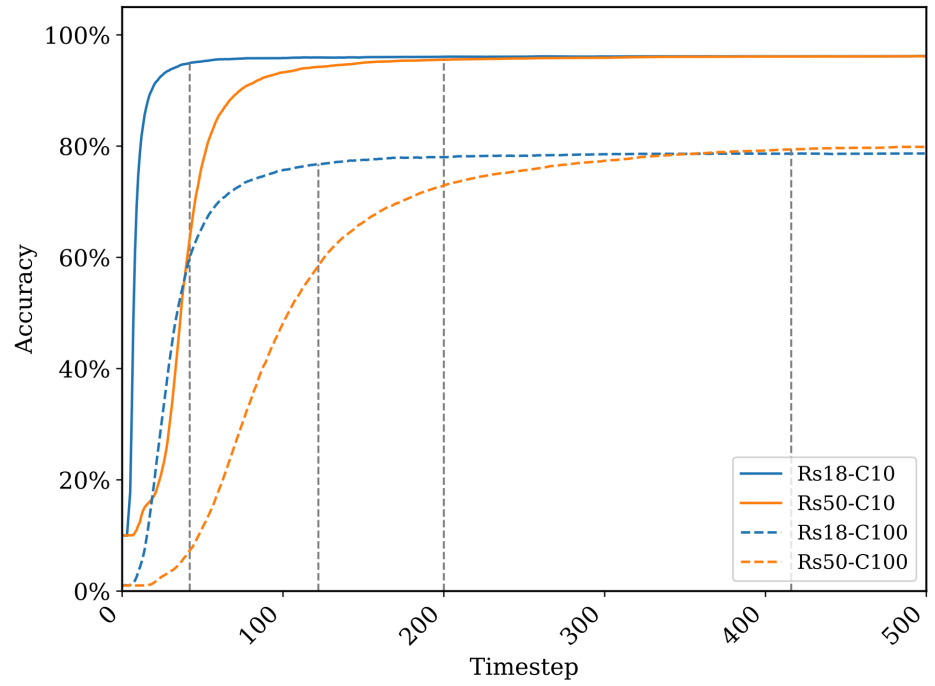
Conventional ANN-to-SNN conversion inherits strong ANN weights, but discrete spike quantization errors accumulate through depth. High fidelity often requires long inference windows.

416

timesteps for ResNet-50 / CIFAR-100 to reach 95% final accuracy.

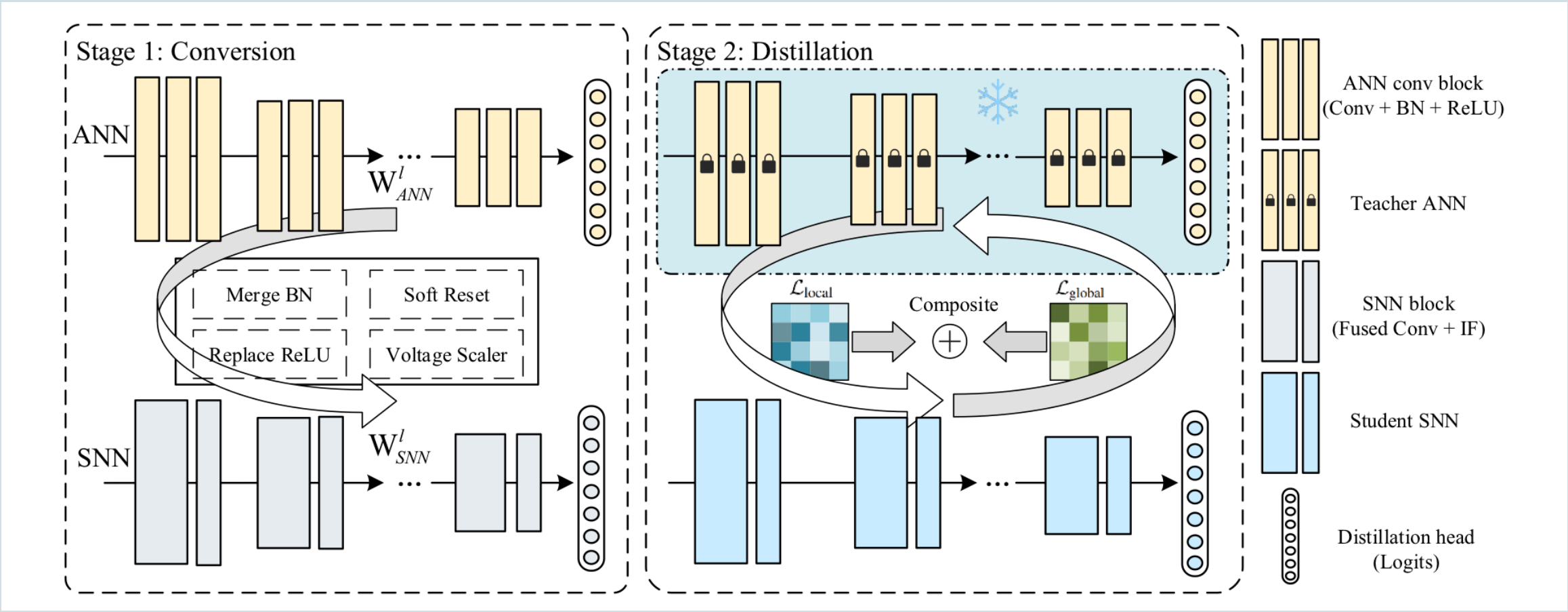
9.90x

relative latency compared with ResNet-18 / CIFAR-10.



METHOD

Closed-loop CKA distillation framework



Stage 1 maps a pretrained ANN into a student SNN. Stage 2 repairs conversion errors with teacher-guided dual alignment: global logits plus adaptive local CKA feature geometry.

OBJECTIVE

Dual alignment repairs semantic and representational drift

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L_total = (1−a)L_task + a[bL_global + (1−b)L_local]
```

1 **Global output feedback**

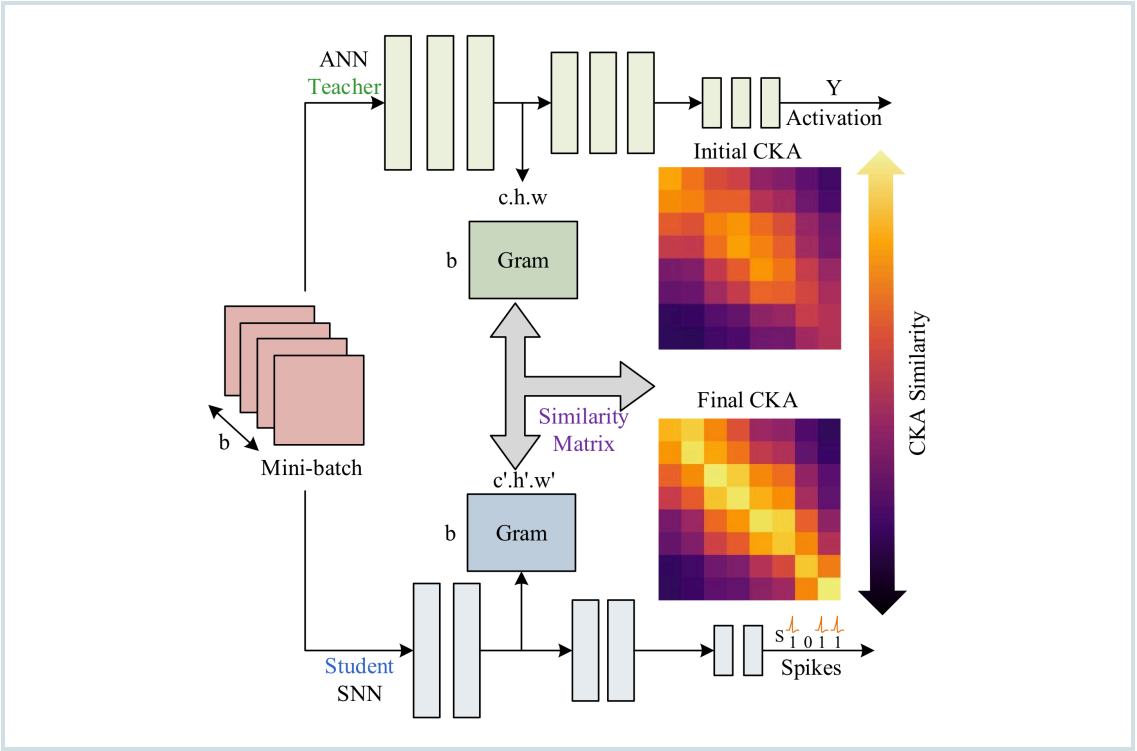
Align teacher ANN logits with SNN firing-rate logits via KL distillation.

2 **Adaptive local CKA**

Align intermediate representation geometry and prioritize layers with severe initial drift.

3 **Time-dependent behavior**

Local CKA stabilizes low-latency regimes; global alignment becomes stronger as firing rates converge.



Fine-tune only the student SNN; keep the teacher ANN frozen

RESULTS

Low-latency fidelity improves while robustness is preserved

90.05%

ResNet-18 / CIFAR-10 at T=2; baseline is 10.00%.

95.33%

ResNet-18 / CIFAR-10 at T=8, already close to source accuracy.

96.38%

T=32 versus 96.39% for the source ANN.