Energy-Efficient Sensor Platform using Reliable Analog-to-Feature Extraction

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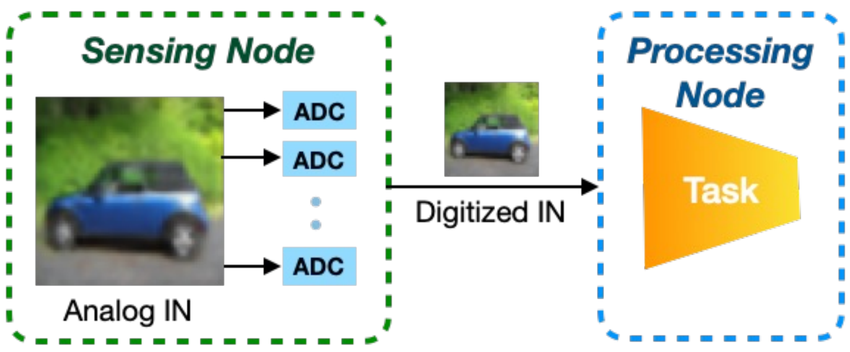
I. Motivations

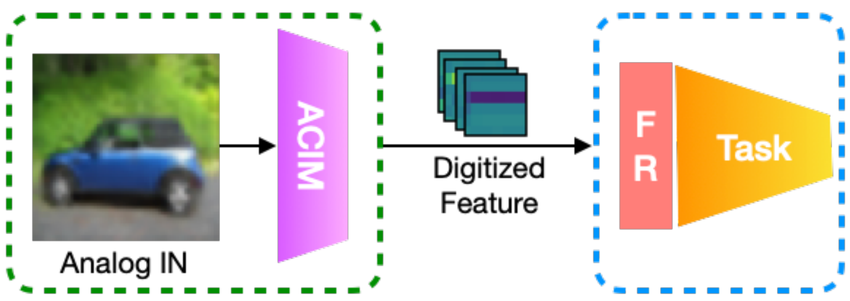
❑ Baseline



- Requires Digitization & Transmission of the Entire Data

  → Significant Energy Consumption

❑ Analog Compute-in-Memory (ACIM) based Perception



- ACIM: 1) Reduce Data Dimension

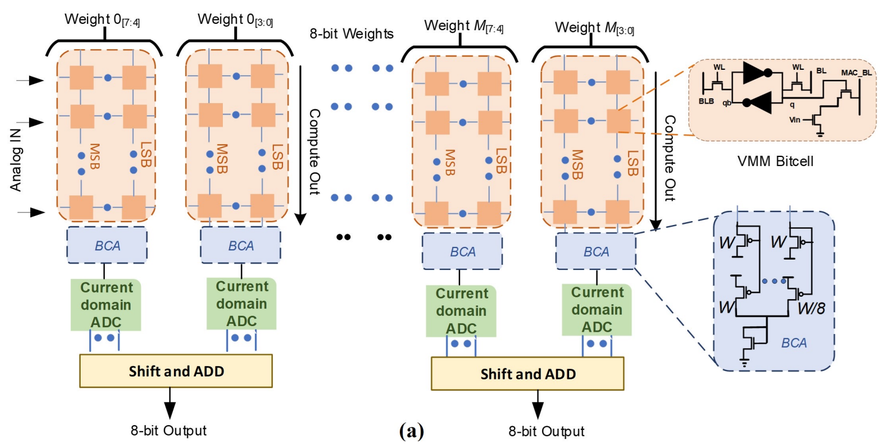
  2) Extract Task-Relevant Features

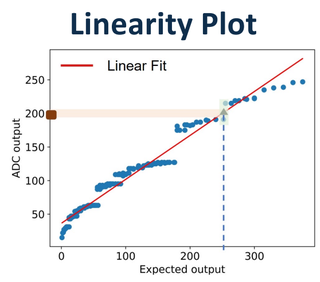
  → Digitization & Transmission of the Extracted Feature

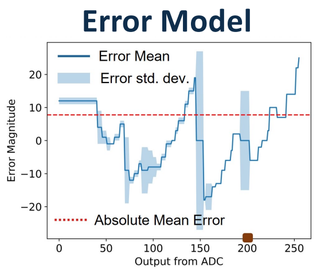
  → Significant Energy Saving

II. Analog Compute-in-Memory

❑ Analog Feature Extraction (AFE) - CIM

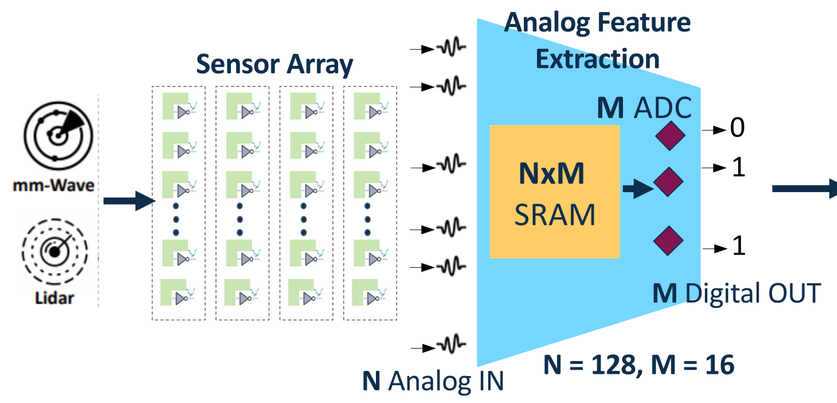






- ACIM cause Computation Errors due to its Inherent Non-linearity
- ADC-output Referred Error Model is Developed

III. ACIM-based Sensor Platform

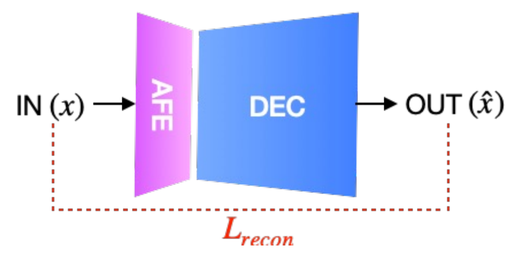


Data Compression Rate

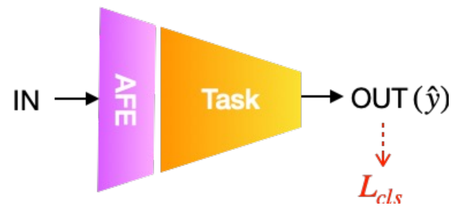
$$r = \frac{W_{in} \times H_{in} \times C_{in}}{W_{out} \times H_{out} \times C_{out}}$$

❑ Training Framework

[Step 1] AFE Training in Autoencoder Architecture



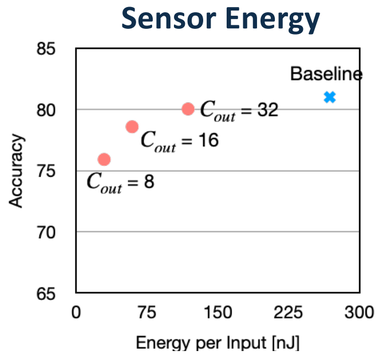
[Step 2] End-to-end Training of AFE and Perception Task



* Dataset: CIFAR10, Task: Resnet18 Variant

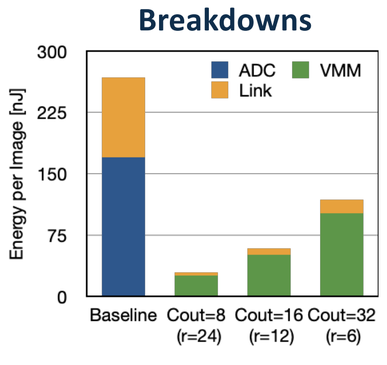
❑ Results

Task Accuracy vs Sensor Energy

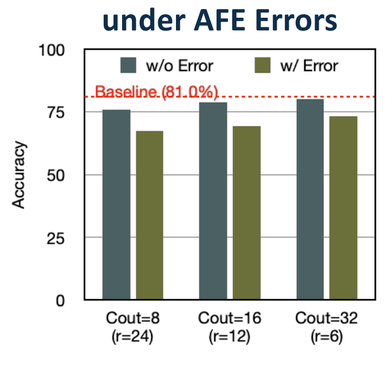


2.4-5% Accuracy Drop
78-89% Energy Saving

Sensor Energy Breakdowns



Accuracy Changes under AFE Errors

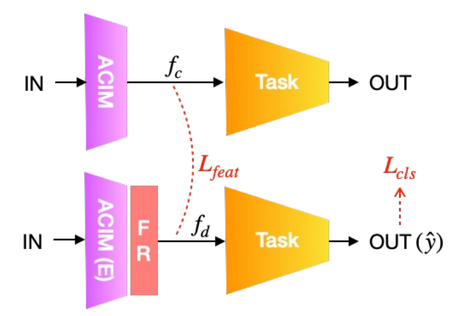


7-8.6% Accuracy Drop

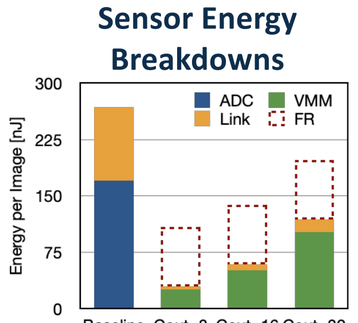
- Data Compression Rate provides the Trade-off between Energy and Accuracy.
- AFE Errors lead to Task Degradation.

IV. Feature Restoration of ACIM

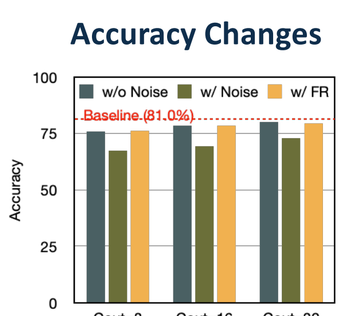
❑ Training Framework ❑ Results



Sensor Energy Breakdowns

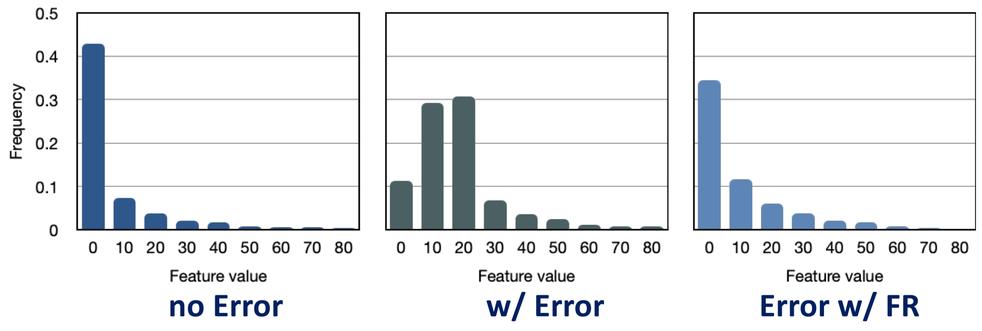


Accuracy Changes



26-60% Energy Saving *1.5-5% Accuracy Drop*

Distribution of Output Feature Map from AFE



V. Conclusions

- This work have explored the energy and task accuracy in ACIM-based sensor platform. We present the trade-off between sensor energy and task performance across *different data compression rates*.
- A Feature Restoration (FR) network is also developed to improve the distorted features from ACIM.
- Simulation results show a 77.9% energy savings (48.5% if FR is implemented in sensor) with 2.4% accuracy drop in ACIM-based sensor platform.

Acknowledgments

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