Background & Motivation

- Federated Learning is a distributed machine learning paradigm that is most used where data is distributed across many devices such as cell phones, or multiple computer networks.
- Current federated learning paradigms are bulky and costly, so it is difficult to implement such systems onto low power devices that have limited resources and power.
- One avenue to reducing the cost of FL is Hyperdimensional computing (HDC), a lightweight and resource efficient paradigm.
- HDC encodes data into high dimensional vectors called hypervectors. Training is performed by comparing query vectors with class vectors.
- Datasets are encoded to class hypervectors.
- Query images are encoded and categorized to the most similar class hypervector in one-pass training.

Problem Statement

We aim to improve federated learning systems with the addition of HDC in place of a neural network such that these systems may perform better on low power devices. We will evaluate our work in terms of accuracy, communication cost and energy efficiency, and robustness against noisy communication channels.

We used FedML, which is an existing Federated Learning framework, in a real deployment of Raspberry Pi’s. We then modified FedML to have edge devices locally train hypervectors and send them to the server for aggregation after completing training.

Animal Classification with HDC

- Datasets are encoded to class hypervectors.
- Query images are encoded and categorized to the most similar class hypervector in one-pass training.

Results and Evaluation

We measured the accuracy, power consumption, and model performance under different level of communication noisy (Gaussian Noise). In addition, we also measure the average communication size and time-to-converge for each model.

- For HDC, we used 1 local epoch whereas CNN used 10 local epoch.
- For both HDC and CNN, we used 6 client, 20 communication rounds and 500 local sample per client.

Accuracy of HDC vs CNN Measured Over Time

Energy Usage and Time of HDC vs CNN

Time: total time used for accuracy to converge.

Average Model Size for CIFAR10

- Baseline Training Time (s)
- HD Training Time (s)
- Baseline Energy Usage (J)
- HD Energy Usage (J)

<table>
<thead>
<tr>
<th>Dataset</th>
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*Time: total time used for accuracy to converge.

Analysis

FL with HDC provide:
- Better Accuracy compares to Baseline on complex image dataset
- 6 times less communication cost
- Robustness in noisy communication channels

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