Regularization of Deep Neural Networks for Quantization Robustness

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MOTIVATION

Deep neural nets (DNNs) achieve state of the art performance tasks in machine learning, but challenges exist in deploying DNNs on embedded platforms.

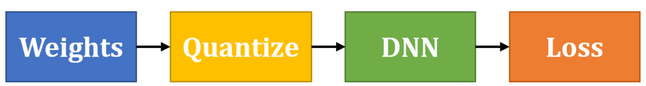
- ❑ **Large model size of millions of parameters requires large memory**
- ❑ **Many operations can lead to large power draw and latency**
- ❑ **Full precision weights not feasible in mobile systems.**

PROJECT AIM

- ❑ **Train DNNs to retain high accuracy under quantization**
- ❑ **Use binary and ternary quantization to limit memory, power consumption**
- ❑ **Employ regularization to ensure weights are robust against quantization**

QUANTIZATION-AWARE TRAINING[1][2]

Forward Pass:



Backpropagation:

- ❑ **Calculate forward pass with quantized weights**
- ❑ **Replace quantizer with identity mapping during backpropagation**

METHOD

Training Procedure

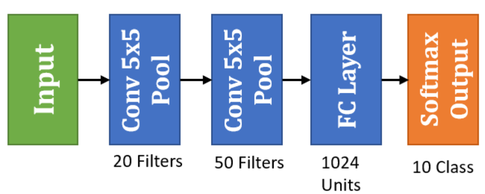
1. **Train network for 30 epochs using quantization-aware update:**
   - $w_{t+1} = w_t - \alpha \frac{\partial L(w)}{\partial Q(w)}$
   - **$L(w)$ is the loss, $Q(w)$ are quantized weights**
2. **Add regularization term to the loss**
   - $L_R(w) = L(w) + \frac{\partial^2 L(w)}{\partial w^2}(w - Q(w))^2$
   - **Regularized update:**

$$w_{t+1} = w_t - \alpha \frac{\partial L(w)}{\partial Q(w)} - \frac{\partial^2 L(w)}{\partial w^2}(w - Q(w))$$

   - **Regularizer forces broad minimum solution (low curvature)**
3. **Train for 20 epochs using $L_R(w)$**

DATASET AND DNN ARCHITECTURE

- ❑ **FashionMNIST 10-class dataset of greyscale images of clothing (T-shirt, sneaker, dress)**
- ❑ **Lenet-5 Network Architecture[3] (2.5 million parameters):**



PRELIMINARY RESULTS

- ❑ **With our approach, DNN retains high performance under quantization of weights and biases**

Quantizer	Quantizer Levels	Test Accuracy
None (baseline)	n/a	92.3% (baseline)
Ternary	[-0.1, 0, 0.1]	92.17 ±.12%
Binary	[-0.1, 0.1]	91.8 ±.17%

Accuracy of Lenet-5 under ternary and binary quantization. Quantizer levels chosen using K-means on weights of normally trained network.

ONGOING & PLANNED WORK

- ❑ **Extend regularization scheme to other network architectures such as VGG, ResNet, etc, and other datasets like CIFAR10, ImageNet.**
- ❑ **Quantize activations in addition to weights and bias values.**
- ❑ **Deploy and evaluate model on embedded platform.**

REFERENCES

[1]M. Courbariaux, Y. Bengio, J.P. David, "Binaryconnect: Training deep neural networks with binary weights during propagations," Advances in Neural Information Processing Systems, 2015.

[2] M. Rastegari, V. Ordonez, J. Redmon, and A. Farhadi, "Xnornet: Imagenet classification using binary convolutional neural networks," European Conference on Computer Vision, 2016.

[3] Y. LeCun, "LeNet-5, convolutional neural networks," November 2013.

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