Towards understanding how momentum improves generalization in deep learning

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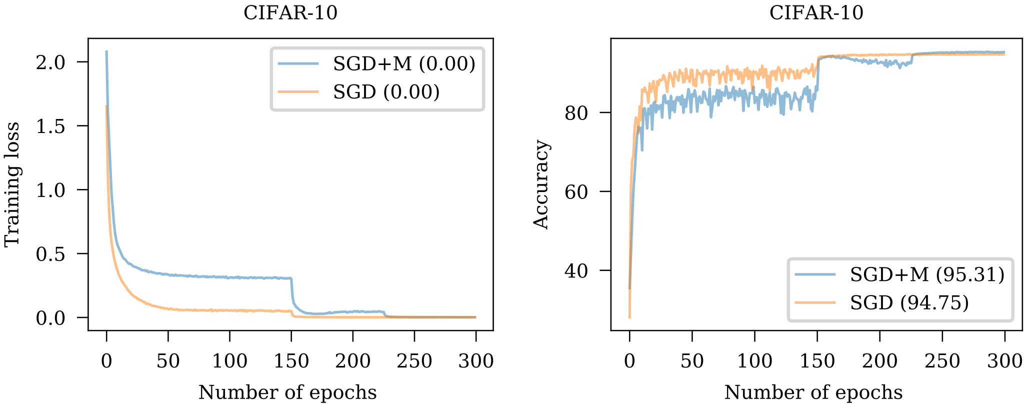
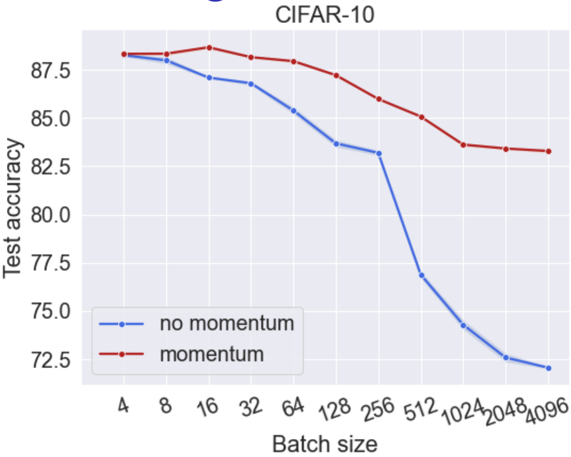
Momentum improves generalization on CIFAR-10



ResNet-18 trained with **data augmentation** and **batch normalization** on CIFAR-10 for 300 epochs. SGD with momentum (SGD+M) gets higher generalization compared to vanilla SGD.

Sutskever, I., Martens, J., Dahl, G., & Hinton, G. (2013). On the importance of initialization and momentum in deep learning.

Is the generalization improvement tied to the stochastic noise in the gradient?



VGG-19 trained on CIFAR-10 for 300 epochs. We **turn off** data augmentation and batch normalization. The generalization improvement gets larger as the batch size increases.

Does momentum unconditionally improve generalization in deep learning?

Answer: No ! Binary classification instance with Gaussian data.

Teacher Student	1-MLP	2-MLP	1-CNN	2-CNN
1-MLP	1.00	1.00	1.00	0.99
2-MLP	0.99	1.00	0.99	0.99
1-CNN	0.99	1.00	1.00	1.01
2-CNN	1.00	1.00	1.00	1.02

Ratio Test(GD+M)/Test(GD) when training ReLU networks on **Gaussian** synthetic dataset. Training for 1000 epochs to ensure tiny training error. Averaged over 3 runs.

Main message of this talk

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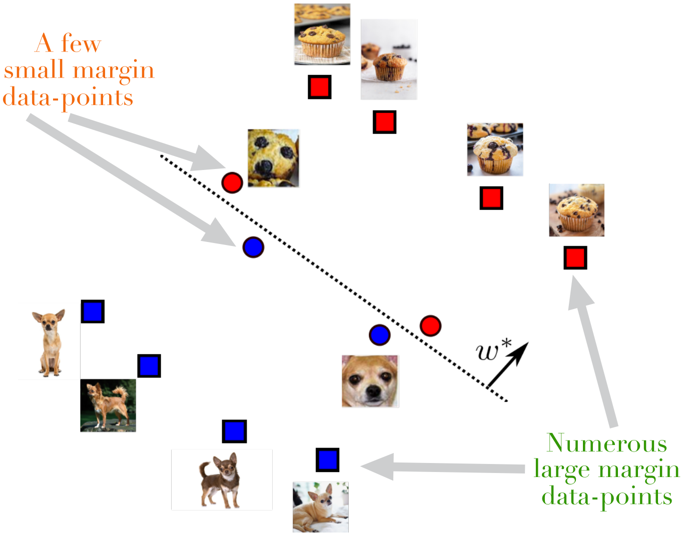
Contribution: We construct a binary classification problem where GD+M provably outperforms GD in terms of generalization. Such improvement cannot be obtained by tuning the learning rate in GD.

Our binary classification dataset



Theorem

There exists an over-parametrized two-layer CNN such that trained on our binary classification dataset:

	Training loss	Test accuracy (large margin data)	Test accuracy (small margin data)
Gradient Descent	✓	✓	✗
Gradient Descent + momentum	✓	✓	✓

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Key insight: Historical gradients in momentum gradient help to learn small margin data.

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Poster: Hall E #237