Lab CudaVision
Learning Vision Systems on Graphics Cards (MA-INF 4308)

Optimization and Learning

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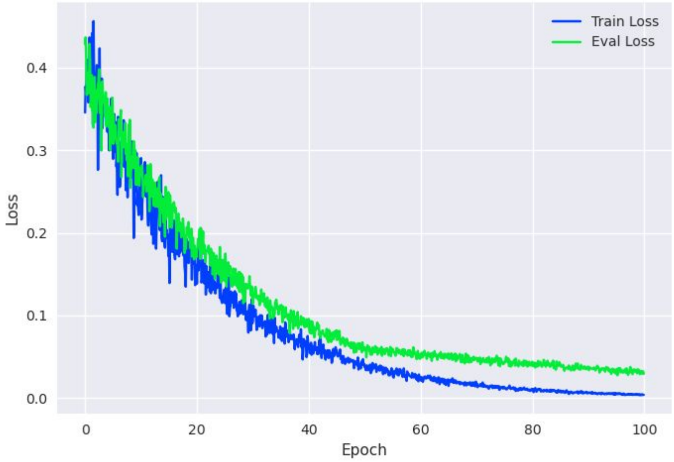
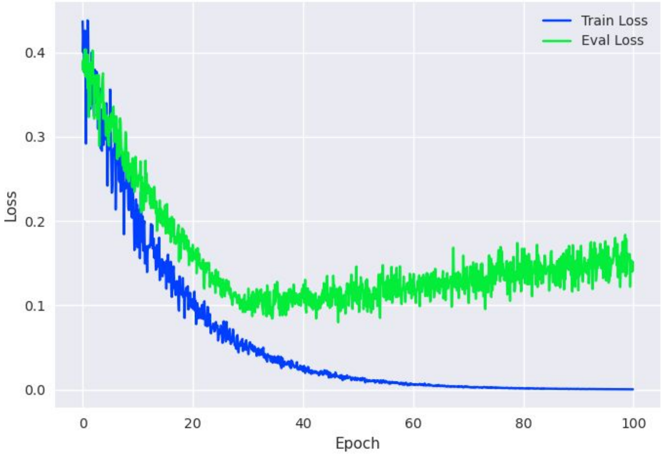
Understanding Learning Curves

Training and Evaluation Curves

- Give us information about how the model performs
  - Learning from training set
  - Generalization on validation set

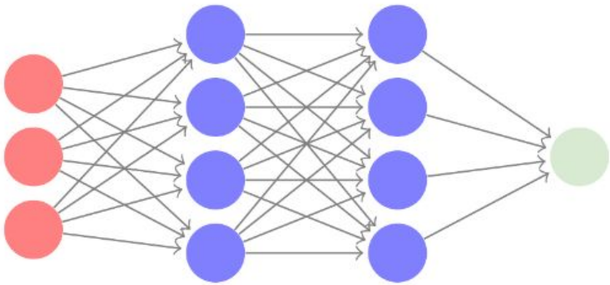
However...





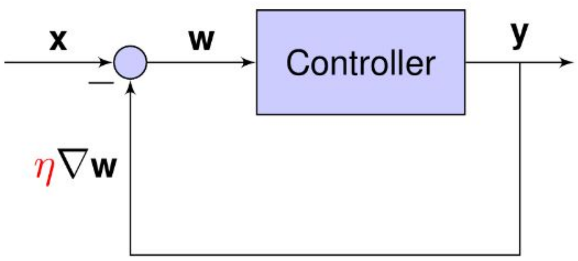
Stability in Neural Networks

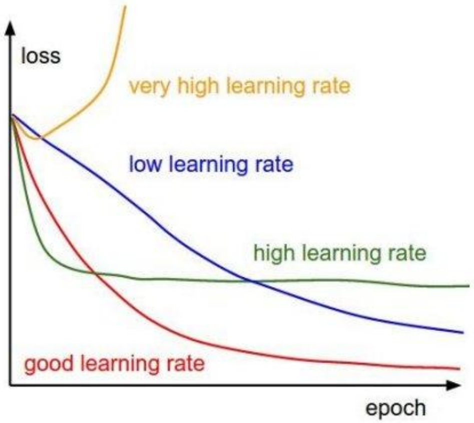
- What do these two images have in common?



- Both suffer from positive feedback
- Wrong choice of hyper-parameters can lead to disaster

Effect of Learning Rate



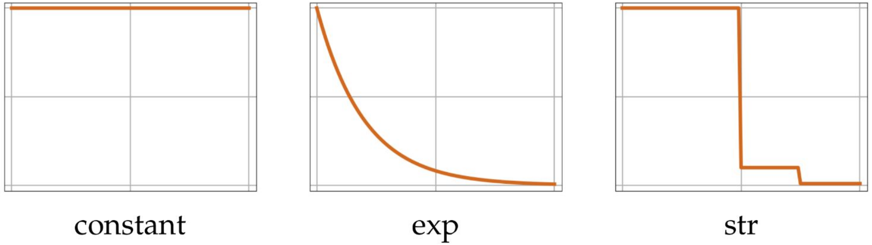


- η too high □ positive feedback □ loss stagnates or even grows
- η too small □ negative feedback □ loss decreases slowly or stagnates
- Choice of η is **critical** for learning!

Dynamic Learning Rates

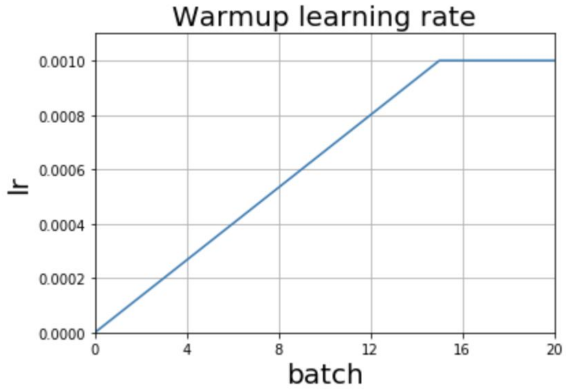
Learning Rate Scheduler

- Adjust the lr during training according to a predefined schedule:
  - Linear
  - Exponential
  - Step-wise
  - On-Plateau



Learning Rate WarmUp

- Increase the learning rate from a very small value to the desired learning rate during the first training iterations
  - Avoid early over-fitting
  - Accelerate convergence

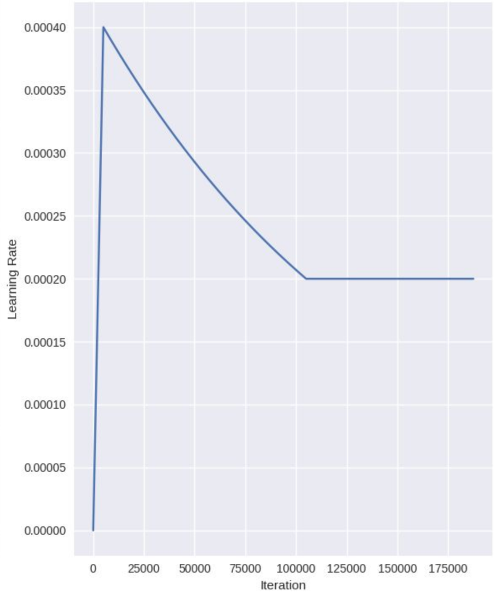


Popular Learning-Rate Curves

LR Warmup + Exponential Scheduler

Alpha = 0.5

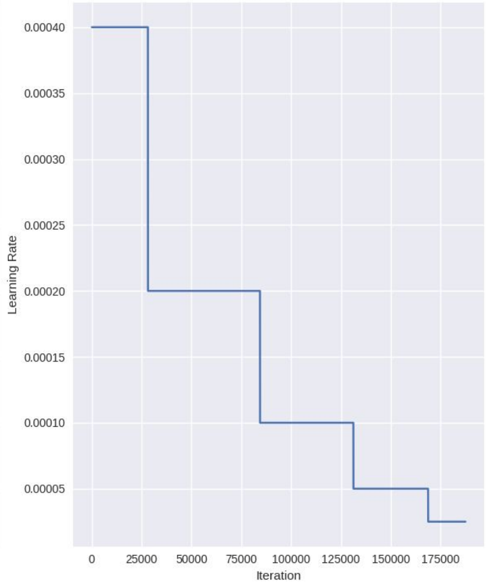
Steps=1e4



Multi-Step Scheduler

LR-Factor = 0.5

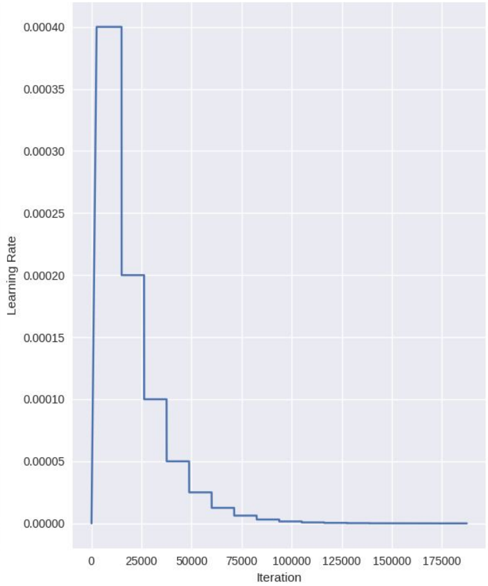
Steps=[15, 45, 70, 90]



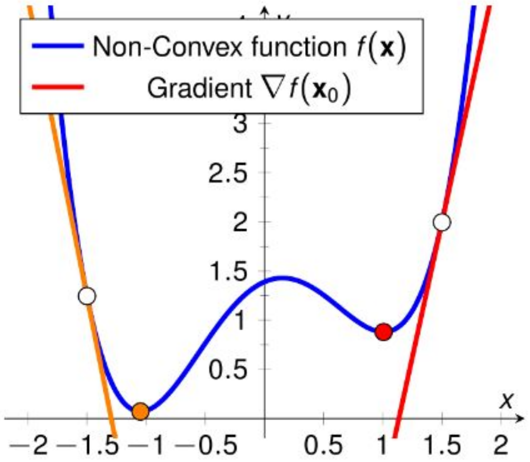
LR Warmup + Plateau Scheduler

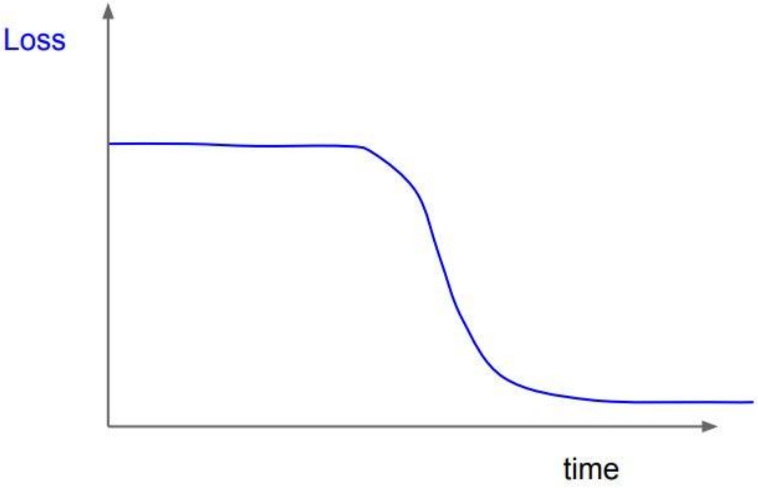
LR-Factor = 0.5

Patience=5



Importance of Initialization

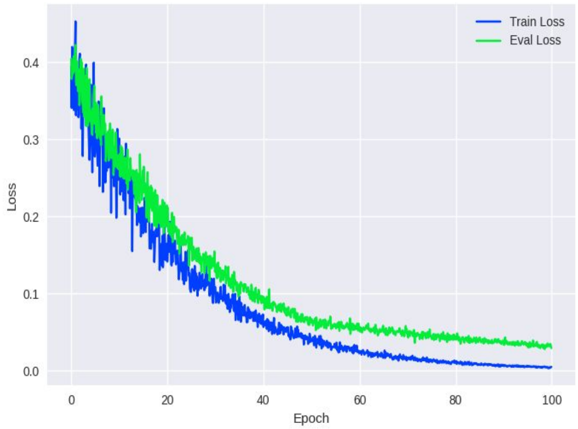




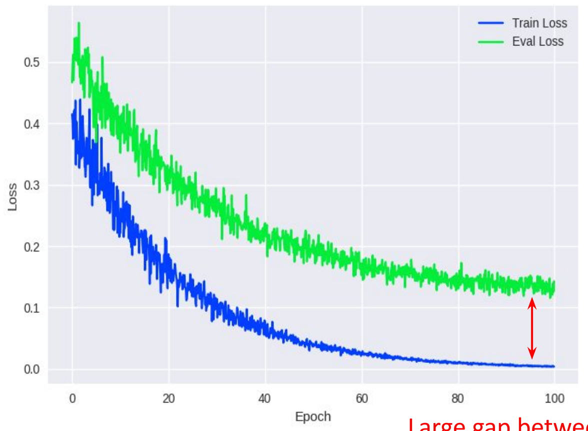
- Use a suitable initialization: Xavier or He
- Use prior knowledge for initialization
- In general, PyTorch's default initialization is quite good

Diagnosing Model Behavior

Successful Training

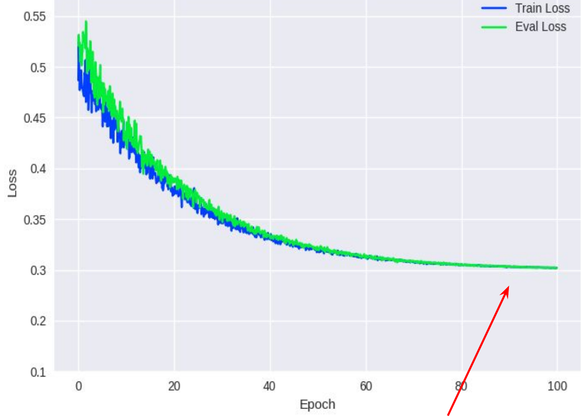


Overfitting



Large gap between train and eval loss

Underfitting



High loss values and no gap between train and eval loss

How to Avoid Underfitting?

- Add more layers to your model

- More powerful architectural designs
  - Residual connections
  - Dense connections

- Clean your data
  - Outliers
  - Noisy labels

How to Avoid Overfitting

- Reduce model capacity

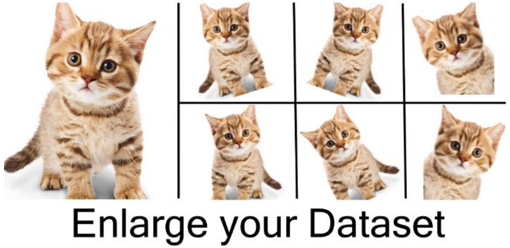
- Use more training examples
  - Gather more data
  - Data augmentation

- Regularization
  - Dropout
  - Weight regularization
  - Early stopping
  - Normalization (e.g. Batch Norm)

Regularization

Data Augmentation

- Artificially enlarging your dataset
- Spatial or pixel transformations



Be careful!

- Generative models

Weight Regularization

- Enforcing certain priors on the model parameters
- Regularization applied to loss function

- **L2 Regularization (*Ridge* or weight decay)**
  - Enforce small parameter norm small parameters

$$\tilde{L}(\mathbf{w}, \mathbf{X}, \mathbf{Y}) = L(\mathbf{w}, \mathbf{X}, \mathbf{Y}) + \lambda \|\mathbf{w}\|_2^2$$

$$\mathbf{w}^{(k+1)} = \underbrace{(1 - \eta\lambda)\mathbf{w}^{(k)}}_{\text{Shrinkage}} - \eta \frac{\partial L}{\partial \mathbf{w}^{(k)}}$$

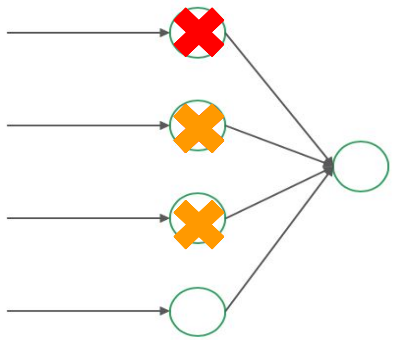
- **L1 Regularization (*Lasso*)**
  - Enforces sparsity in the parameters

$$\tilde{L}(\mathbf{w}, \mathbf{X}, \mathbf{Y}) = L(\mathbf{w}, \mathbf{X}, \mathbf{Y}) + \lambda \|\mathbf{w}\|_1$$

$$\mathbf{w}^{(k+1)} = \underbrace{\mathbf{w}^{(k)} - \eta\lambda \operatorname{sign}\left(\mathbf{w}^{(k)}\right)}_{\text{Other shrinkage}} - \eta \frac{\partial L}{\partial \mathbf{w}^{(k)}}$$

- **L1 + L2 Regularization (*Elastic*)**

Dropout

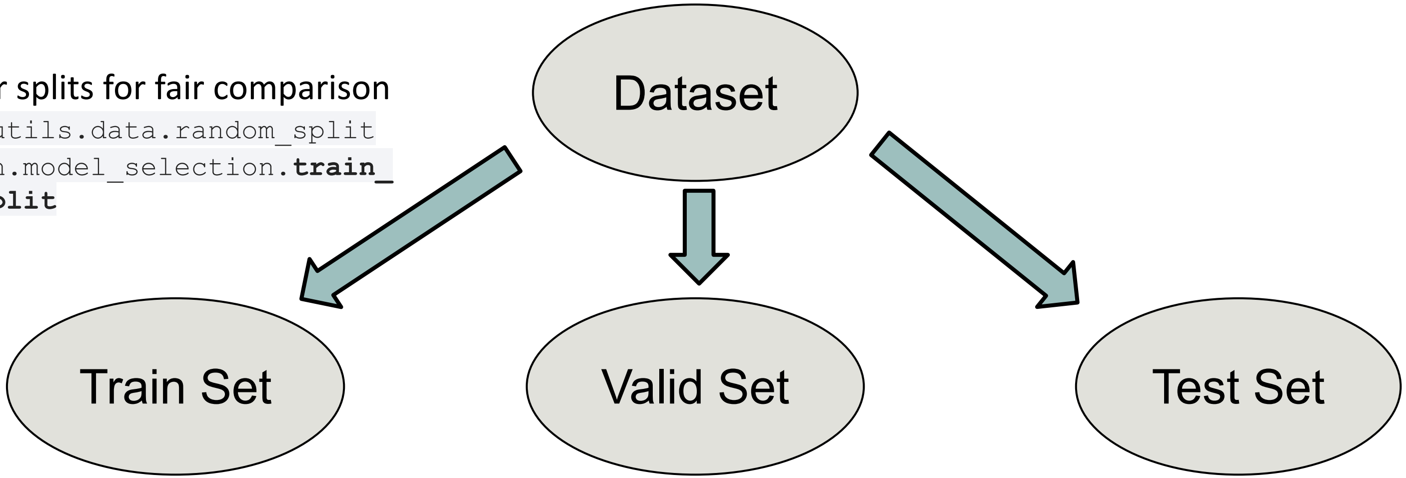


- During training, randomly set activations to zero with probability (*1-p*)
- At test time, we use all activations, but scaled by *p*
- Usual values
  - *p*=0.2 for input layer
  - *p*=0.5 for hidden layers

Dataset Splits

Splitting your Dataset

- Fix your splits for fair comparison
  - `Torch.utils.data.random_split`
  - `sklearn.model_selection.train_test_split`



Train Set
- Train the model
- 60-70% of total

Valid Set
- Parameter Optimization
- Avoid overfitting
- 10-15% of dataset

Test Set
- Evaluate performance
- Never use for training
- 15-20% of dataset

Generate your Dataset

- Annotated data is scarce and expensive to obtain
- Use synthetic data for training

Simple Generation

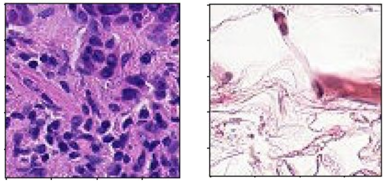
Simulators (CARLA)

Game Engines (GTA V)

Evaluation Metrics

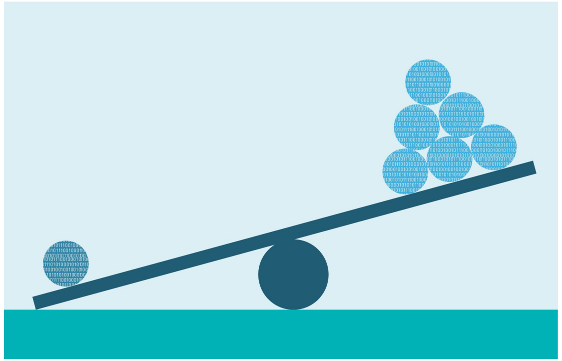
Problem with Accuracy

- "Let's image we are trying to detect if a person has some rare disease that is present in a 0.01% of the population based on some digital pathology scans"



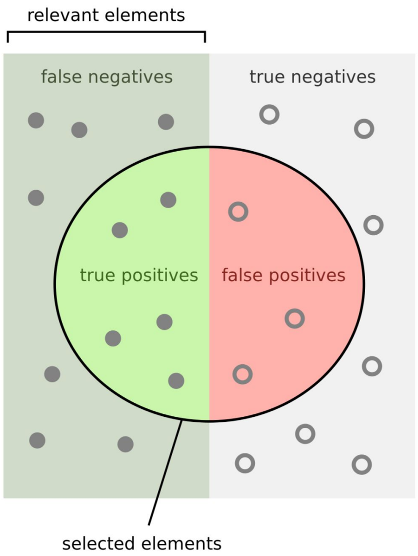
- Always predicting a negative results
    - Correct 99.99% of the time

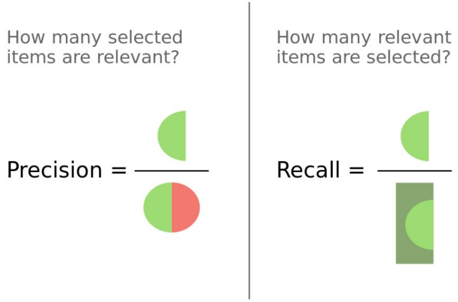
- Accuracy is not always a good metric:
    - Imbalanced datasets
    - Not-permissible mistakes



Precision and Recall

- Precision, Recall and F1-Score are better suited metrics for many pattern recognition problems





$$Precision = \frac{TP}{TP + FP}$$

$$Recall = \frac{TP}{TP + FN}$$

$$F1 = 2 \cdot \frac{precision \cdot recall}{precision + recall}$$