Advanced techniques

Lecture 6

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Hyperparameter search and cross validation

Outline

1. Hyperparameter search

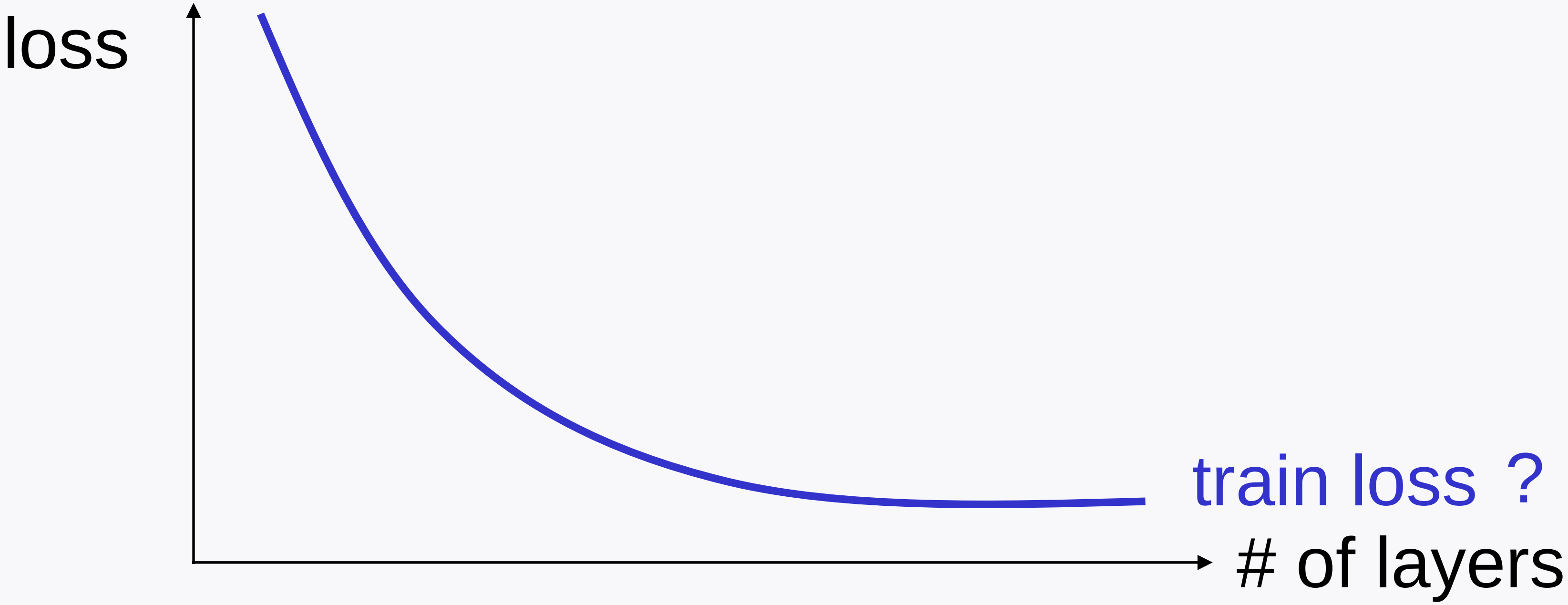
   # *L* of layers, # $n^{[\ell]}$ of hidden neurons, activation learning rate, betas, batch size, # *T* of epochs, regularization factor, dropout rate, …

2. Cross validation

# of layers

Just begin with a **single hidden** layer: $L = 1$

Gradually (linearly) ramp up # of hidden layers.



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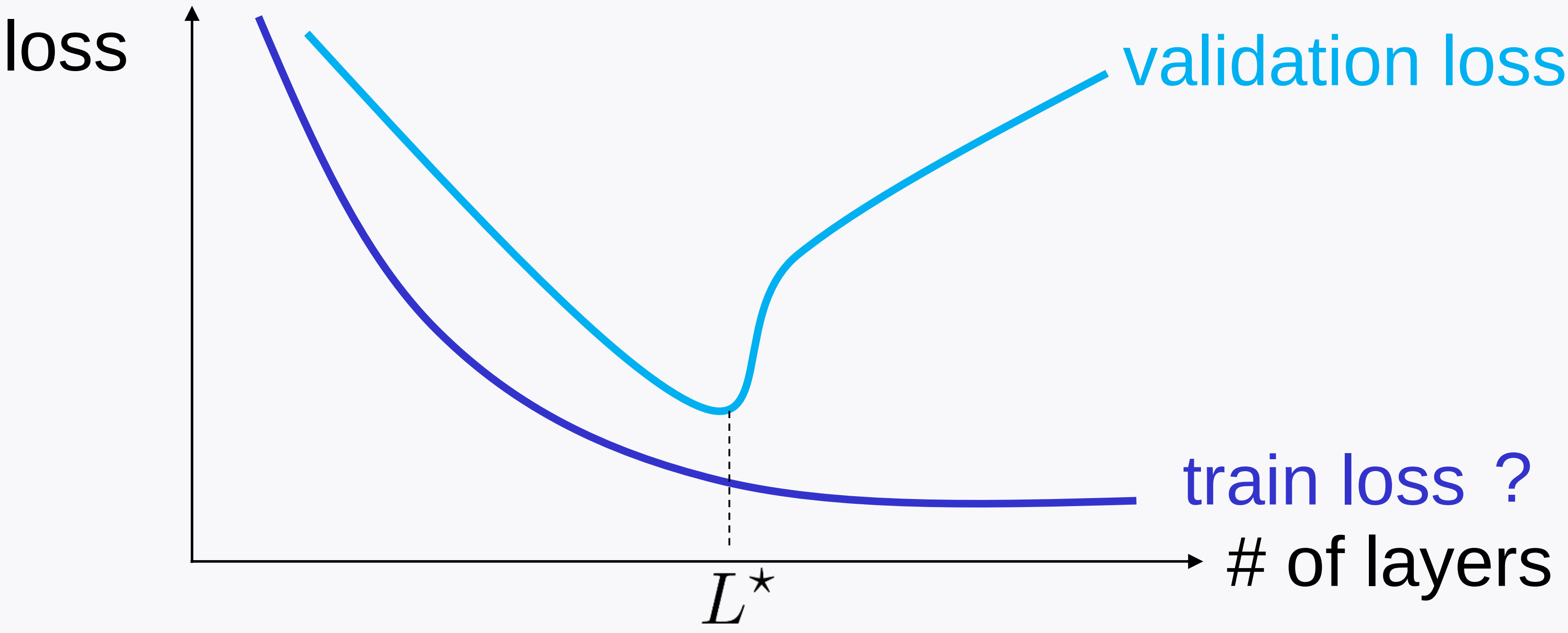


Stop when overfitting starts.

# of layers

When increasing *L*:

How to set the number of hidden neurons for all hidden layers?

For the time being:

Set that number around one half of the number of input neurons:

$$n^{[\ell]} = \frac{n}{2}$$

# of hidden neurons

Two approaches:

1. Fewer neurons for deeper layers

2. Same size for all hidden layers:

   Linearly increase the size until not overfitting.

Activation functions

A default setup:

Hidden layers: ReLU

Output layer: **Softmax** for classification

No activation for regression

Optimizer

A default use: **Adam**

Default parameters: $(\beta_1, \beta_2) = (0.9, 0.999)$

Two approaches for a choice of the learning rate:

1. Learning rate decaying

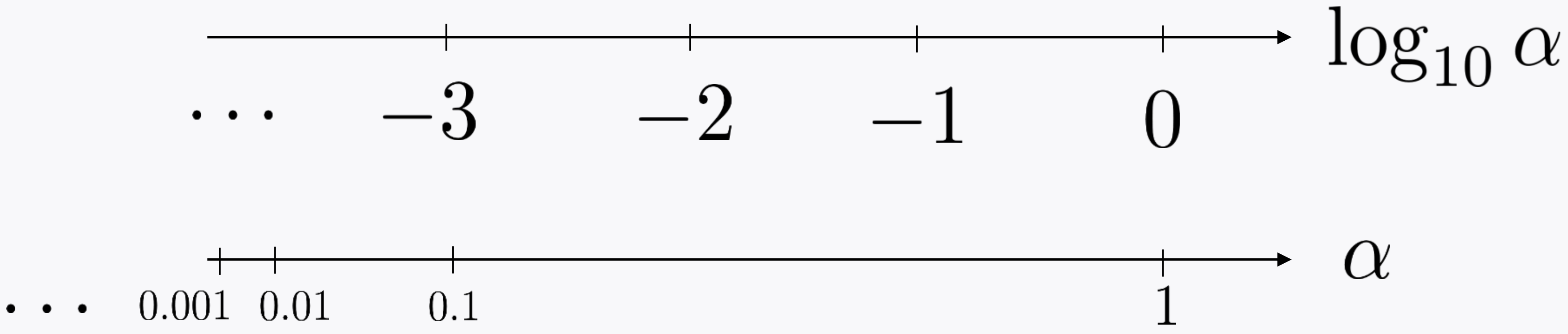
2. Fixed (e.g., $\alpha = 0.001$)

How to choose a fixed value of α

Do not use a linear-scale grid search.

Try **random** values and **then do a fine search** around the good choices.

Grid scale for the fine search: **Log** scale



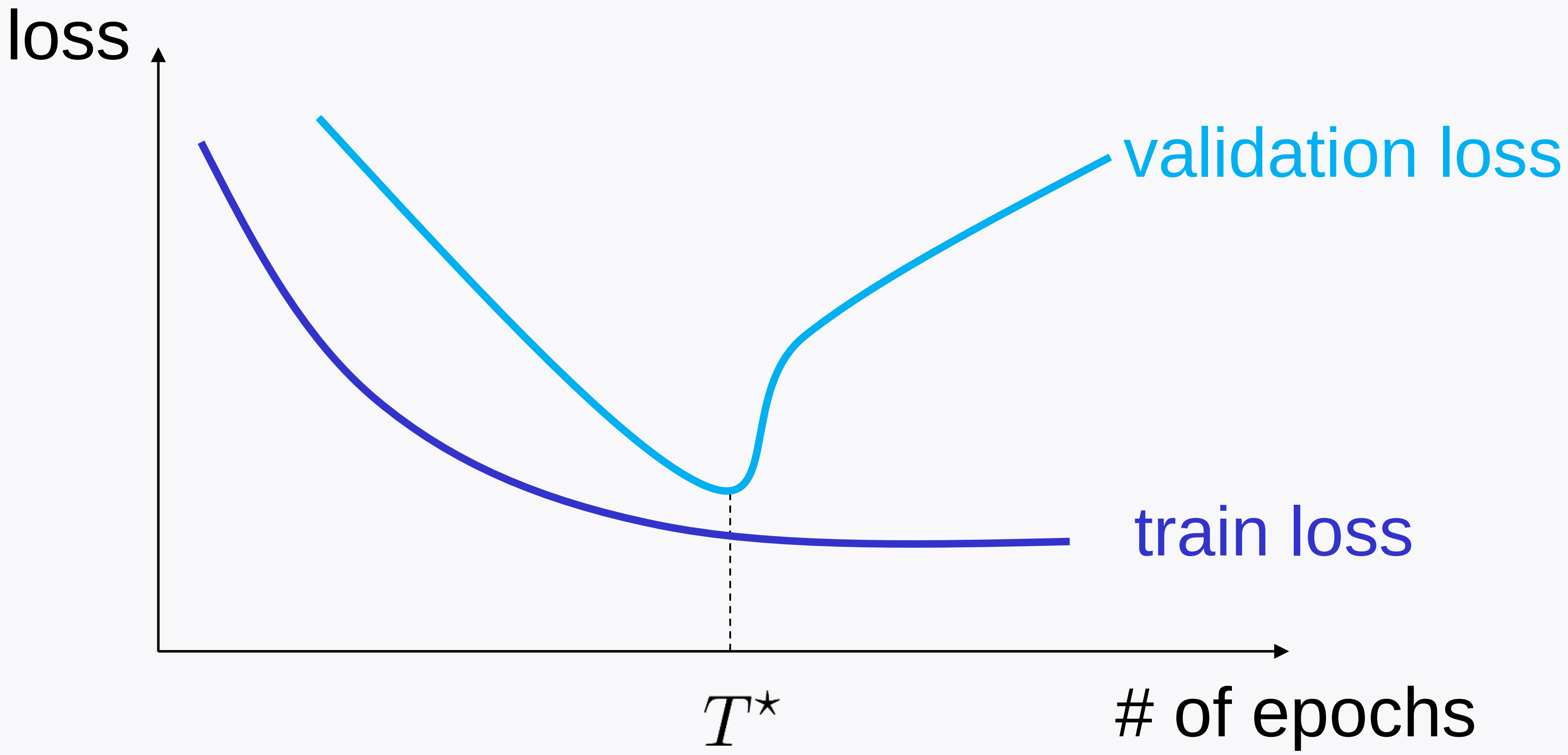
Batch size

A common choice: **Power of two**.

4, 8, 16, 32, 64, 128, 256

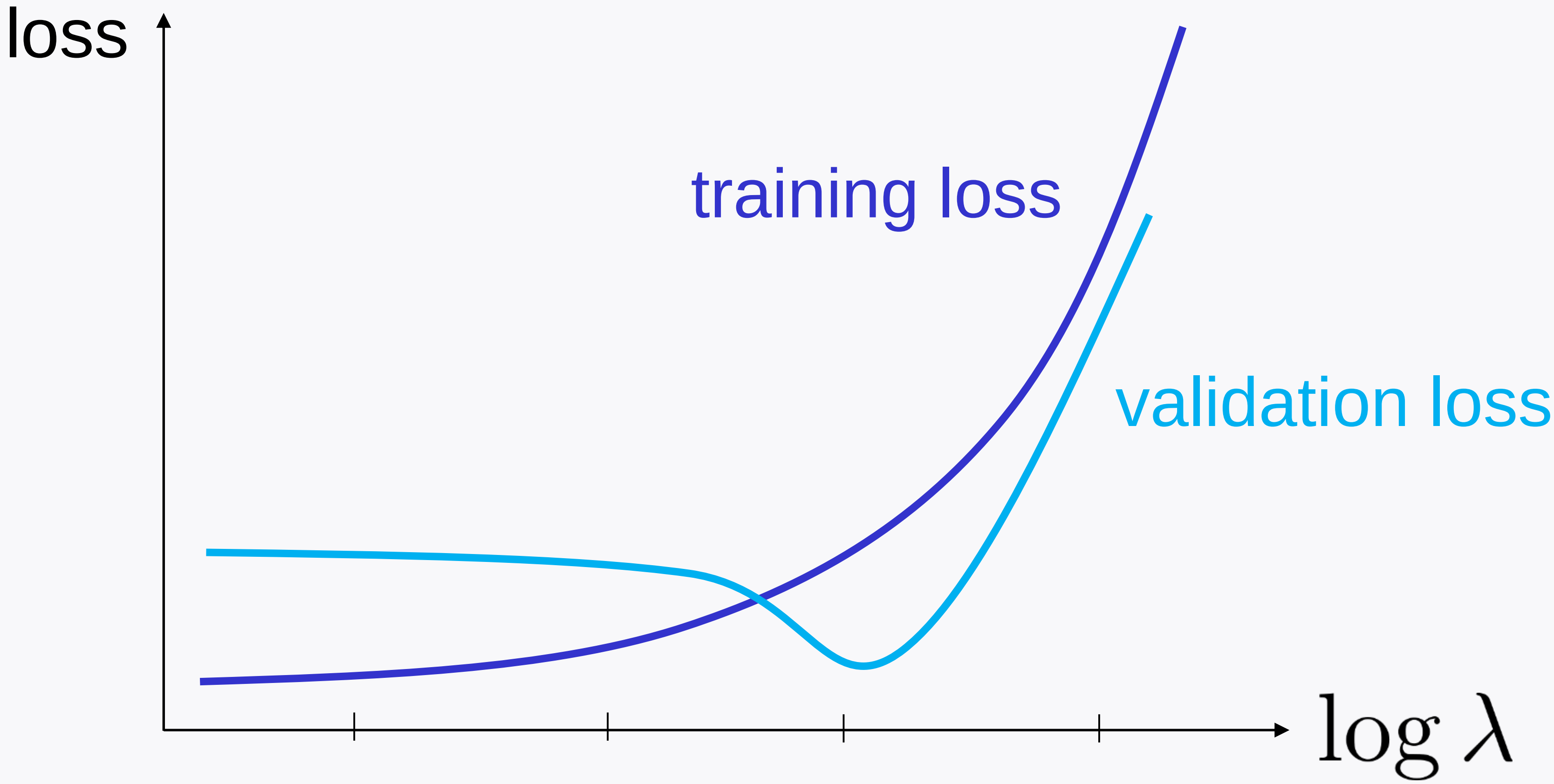
# of epochs

Choose according to **early stopping**:



Regularization factor

Log-scale search:



Dropout rate

A typical choice: $p = 0.5$

A good range: $0.2 \leq p \leq 0.8$

Cross validation

Purpose: Obtain **reliable** validation loss via **averaging.**

→ Helps avoid overfitting

Example: 4-fold cross validation

val	train	train	train	test

→ Compute a validation loss, say val_1

Take the 2nd partition for val:

train	val	train	train	test

→ Compute a corresponding loss: val_2

Cross validation

val	train	train	train	test	val_1
train	val	train	train	test	val_2
train	train	val	train	test	val_3
train	train	train	val	test	val_4

Take the average over the 4 losses:

$$\text{val loss} = \frac{\mathrm{val}_1 + \mathrm{val}_2 + \mathrm{val}_3 + \mathrm{val}_4}{4}$$

Choose a hyperparameter that minimizes the average loss.

A final model w.r.t. the best hyperparameter?

val	train	train	train	test	model_1
train	val	train	train	test	model_2
train	train	val	train	test	model_3
train	train	train	val	test	model_4

Which one to take among the four models?

A final model is the one trained based on:

train	train	train	train	test

What is next?

One important question:

Can DNNs be specialized?

CNNs: Image data

RNNs: Text/audio data (language) and
any sequential data

Outline of Day 3 lectures

Focus on CNNs.

Specifically we will:

1. Investigate how CNNs were developed;
2. Study the two key building blocks:

   Conv layer

   Pooling layer

3. Discuss popular CNN architectures.