General Guidance

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Framework of ML

Training data: $\left\{\left(\boldsymbol{x}^{\mathbf{1}}, \hat{y}^{1}\right),\left(\boldsymbol{x}^{\mathbf{2}}, \hat{y}^{2}\right), \ldots,\left(\boldsymbol{x}^{\boldsymbol{N}}, \hat{y}^{N}\right)\right\}$

Testing data: $\left\{\boldsymbol{x}^{\boldsymbol{N}+\mathbf{1}}, \boldsymbol{x}^{\boldsymbol{N}+\mathbf{2}}, \ldots, \boldsymbol{x}^{\boldsymbol{N}+\boldsymbol{M}}\right\}$

Speech Recognition

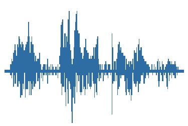
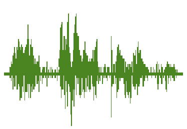
$\boldsymbol{x}$:  $\hat{y}$: phoneme

Image Recognition

$\boldsymbol{x}$:  $\hat{y}$: soup

Speaker Recognition

$\boldsymbol{x}$:  $\hat{y}$: John (speaker)

Machine Translation

$\boldsymbol{x}$: 痛みを知れ

$\hat{y}$: 了解痛苦吧

Framework of ML

Training data: $\{(\boldsymbol{x}^1, \hat{y}^1), (\boldsymbol{x}^2, \hat{y}^2), \dots, (\boldsymbol{x}^N, \hat{y}^N)\}$

Training:

Step 1: function with unknown → Step 2: define loss from training data → Step 3: optimization

$y = f_{\boldsymbol{\theta}}(\boldsymbol{x})$

$L(\boldsymbol{\theta})$

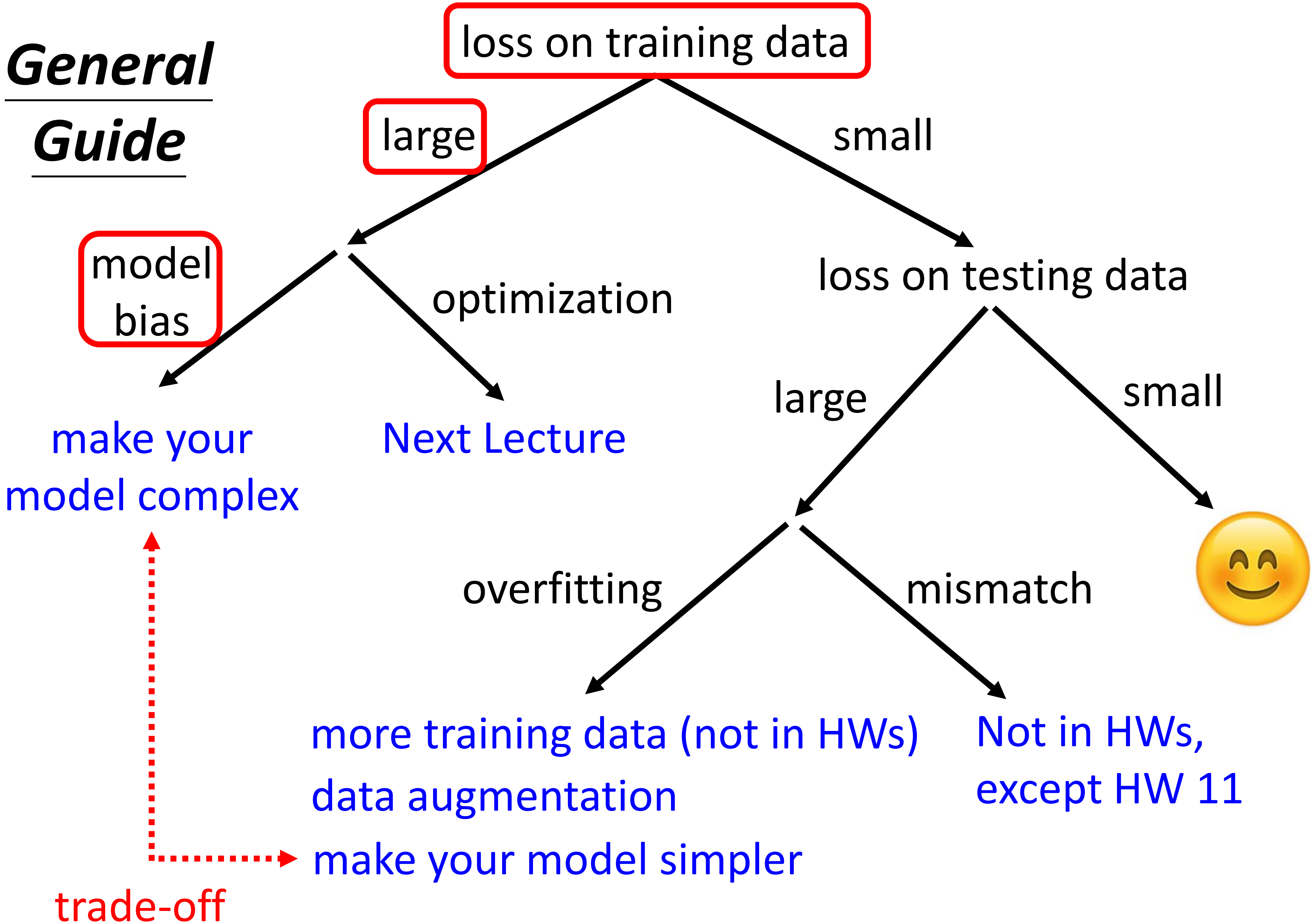
$\boldsymbol{\theta}^* = arg \min_{\boldsymbol{\theta}} L$

Testing data: $\{\boldsymbol{x}^{N+1}, \boldsymbol{x}^{N+2}, \dots, \boldsymbol{x}^{N+M}\}$

Use $y = f_{\boldsymbol{\theta}^*}(\boldsymbol{x})$ to label the testing data

$\{y^{N+1}, y^{N+2}, \dots, y^{N+M}\}$ → Upload to Kaggle

General Guide



Split your training data into training set and validation set for model selection

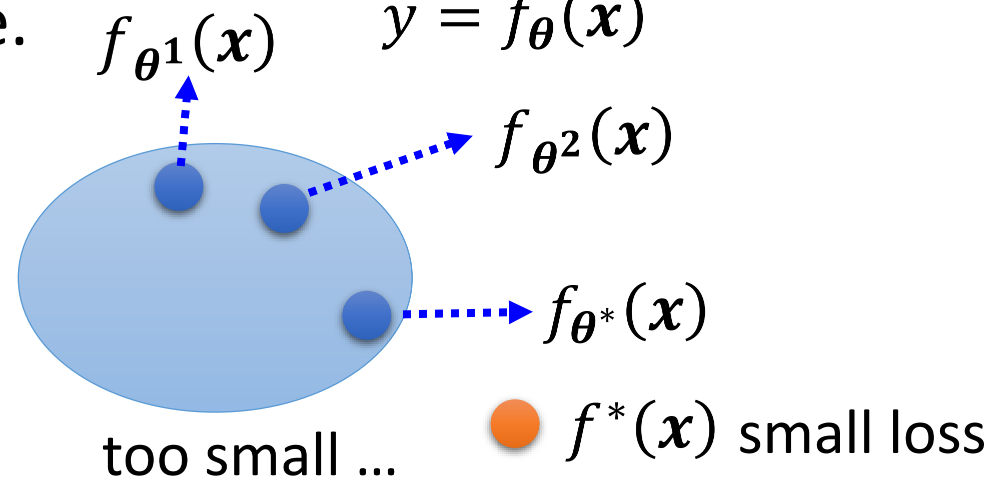
Model Bias

- The model is too simple.

$$y = f_{\boldsymbol{\theta}}(\boldsymbol{x})$$

find a needle in a haystack …

… but there is no needle



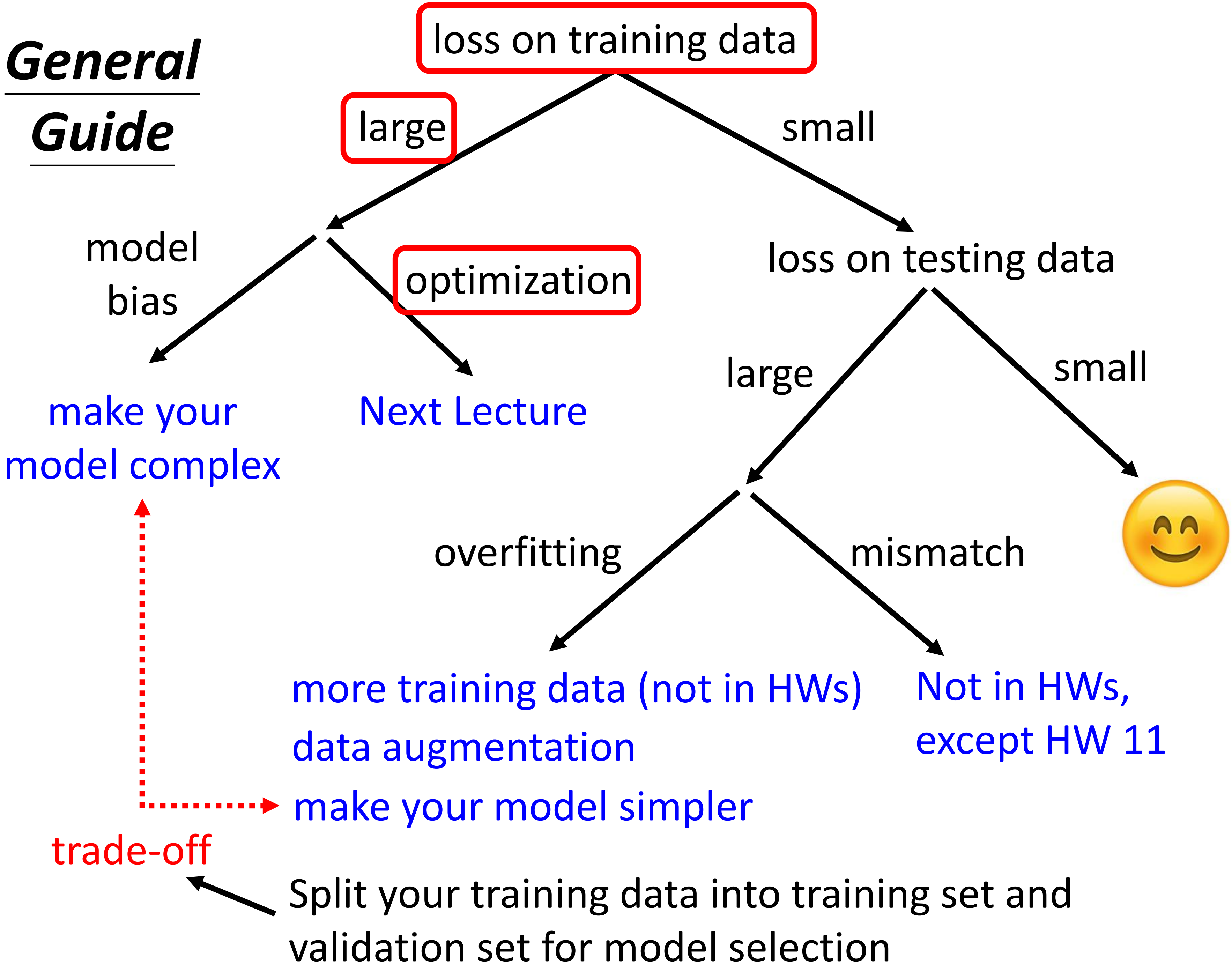
- Solution: redesign your model to make it more flexible

$$y = b + w x_1 \xrightarrow{\text{More features}} y = b + \sum_{j=1}^{56} w_j x_j$$

Deep Learning
(more neurons, layers)

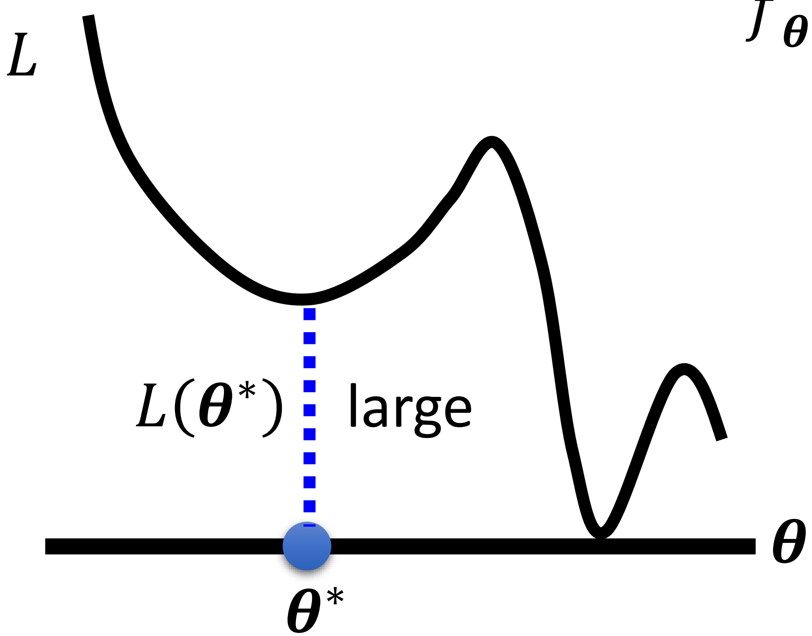
$$y = b + \sum_i c_i \, sigmoid\left(b_i + \sum_j w_{ij} x_j \right)$$

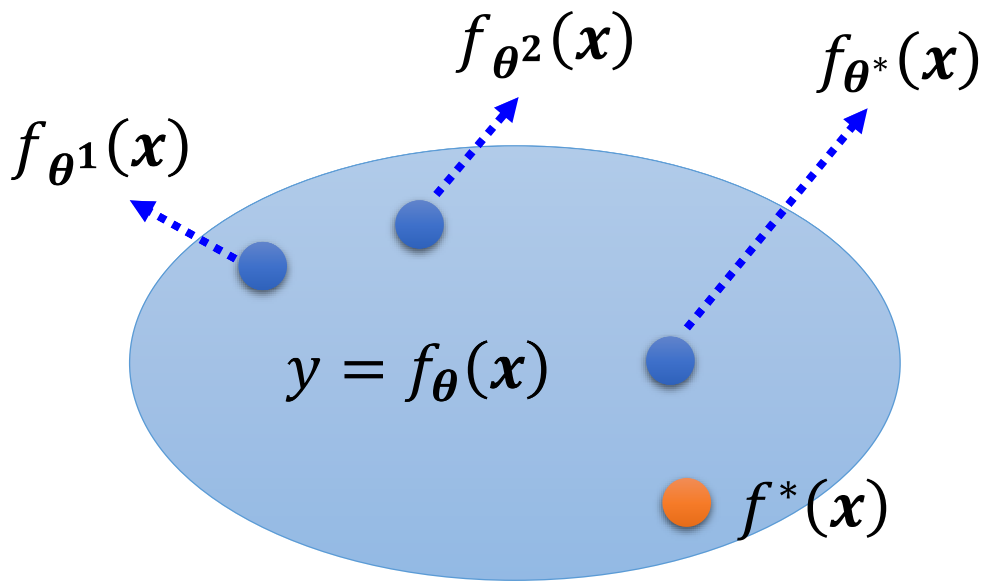
General Guide



Optimization Issue

- Large loss not always imply model bias. There is another possibility ...





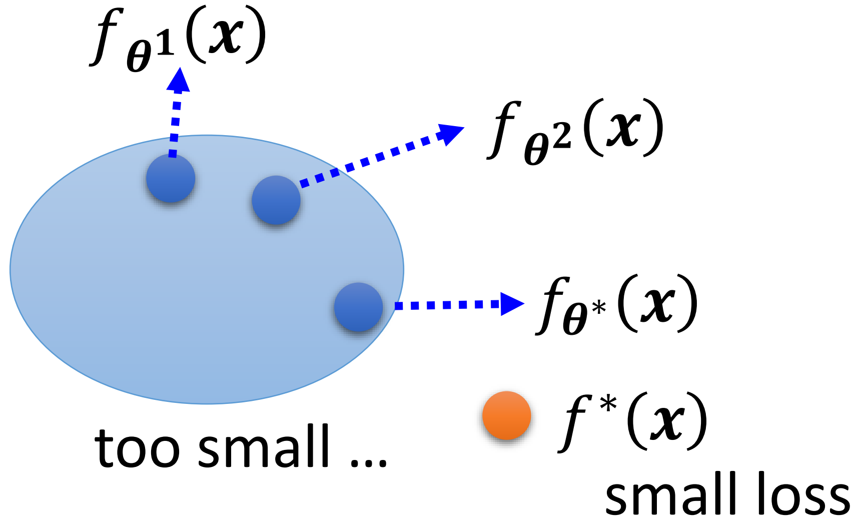
A needle is in a haystack ...

... Just cannot find it.

Model Bias

find a needle in a haystack …

… but there is no needle

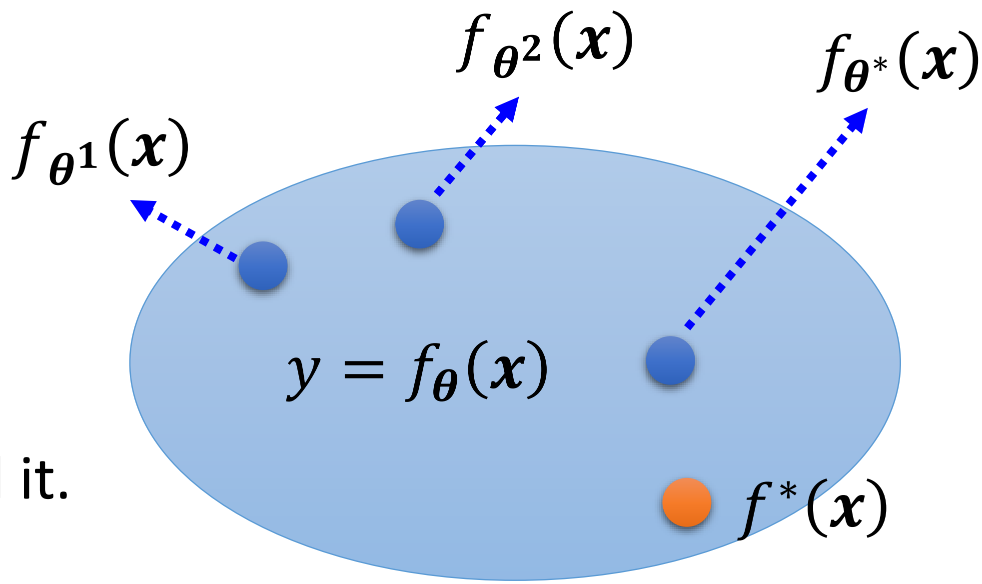


Which one???

Optimization Issue

A needle is in a haystack …

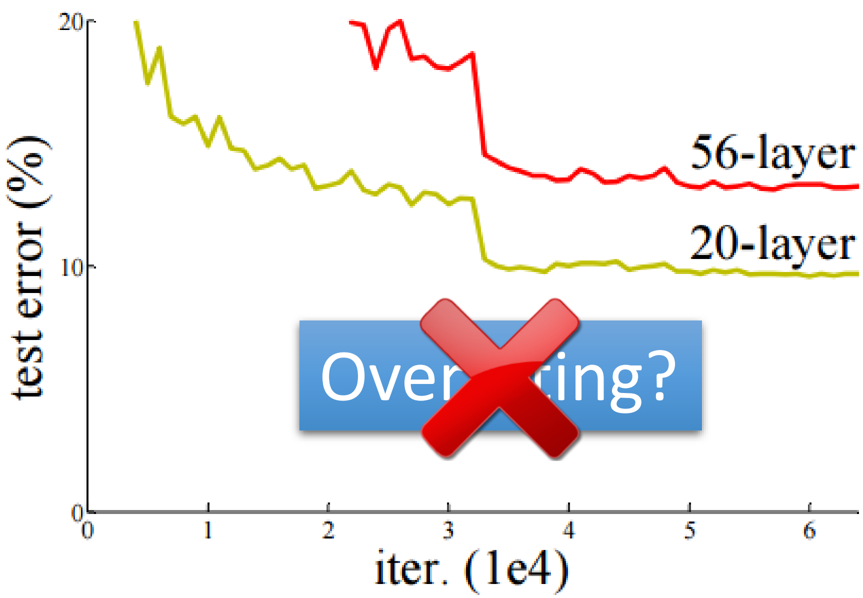
… Just cannot find it.



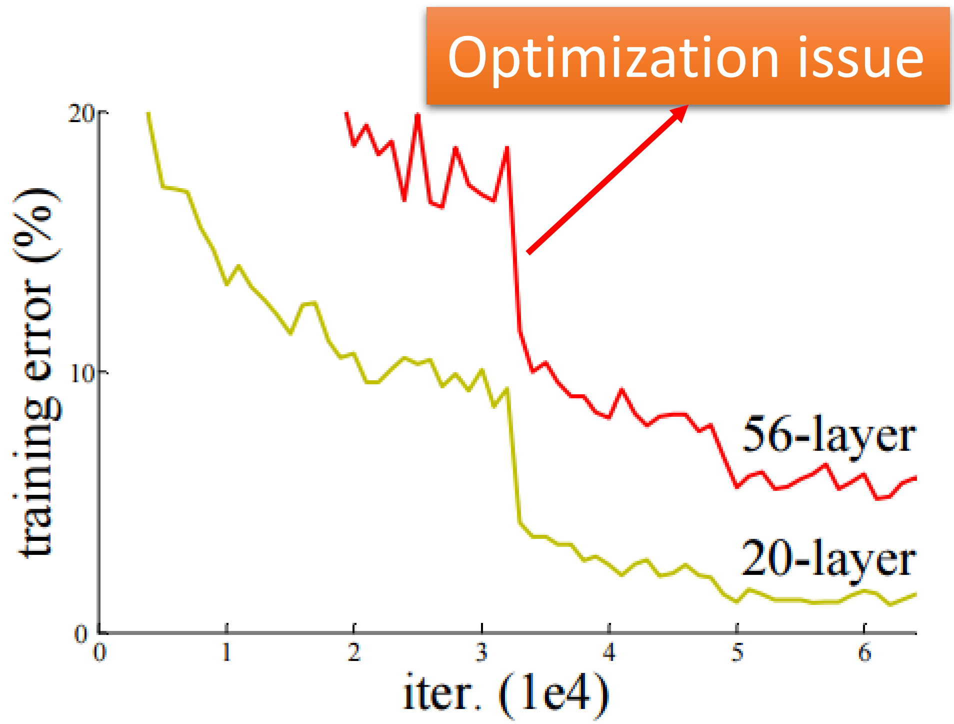
Ref: http://arxiv.org/abs/1512.03385

Model Bias v.s. Optimization Issue

- Gaining the insights from comparison



Testing Data



Training Data

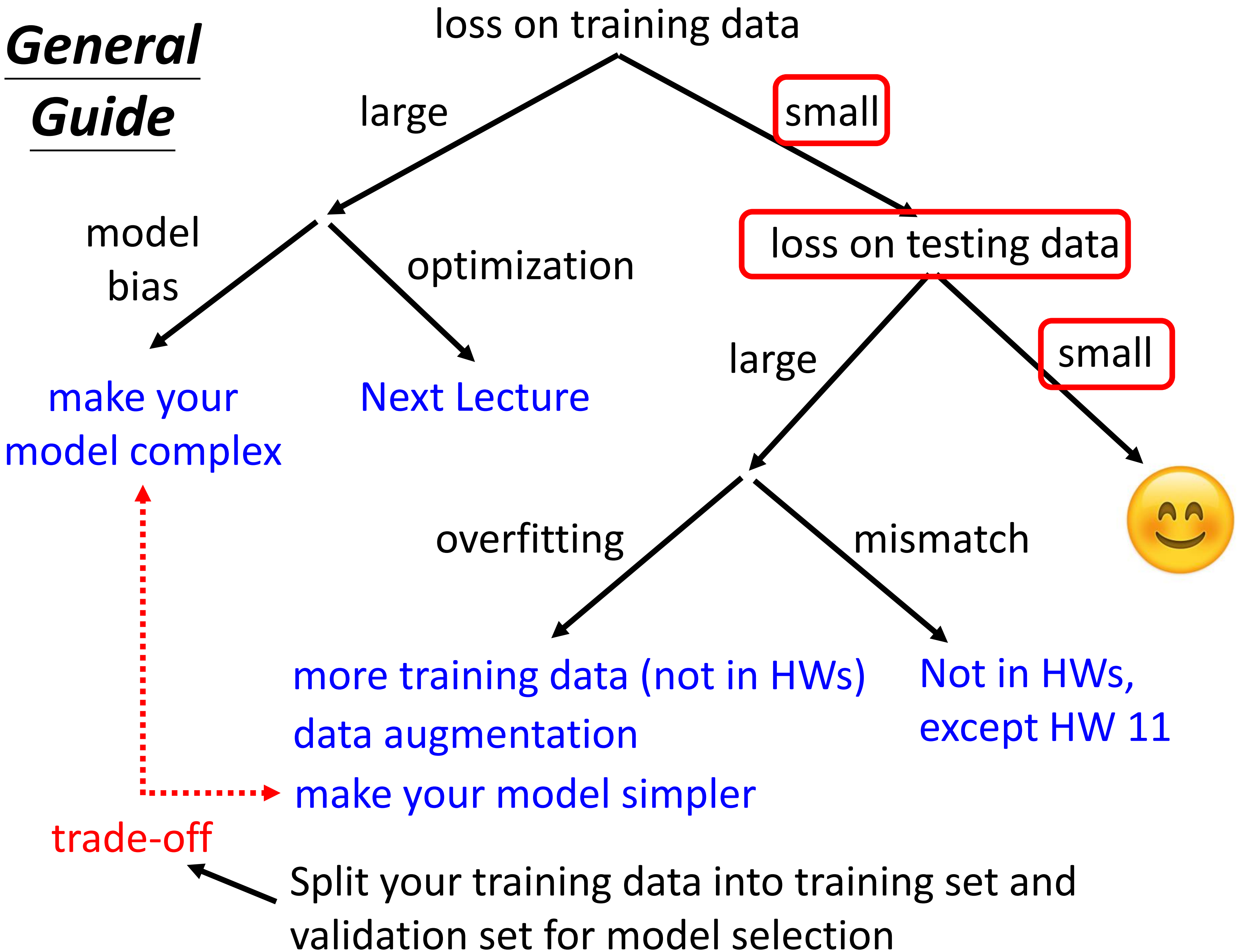
Ref: http://arxiv.org/abs/1512.03385

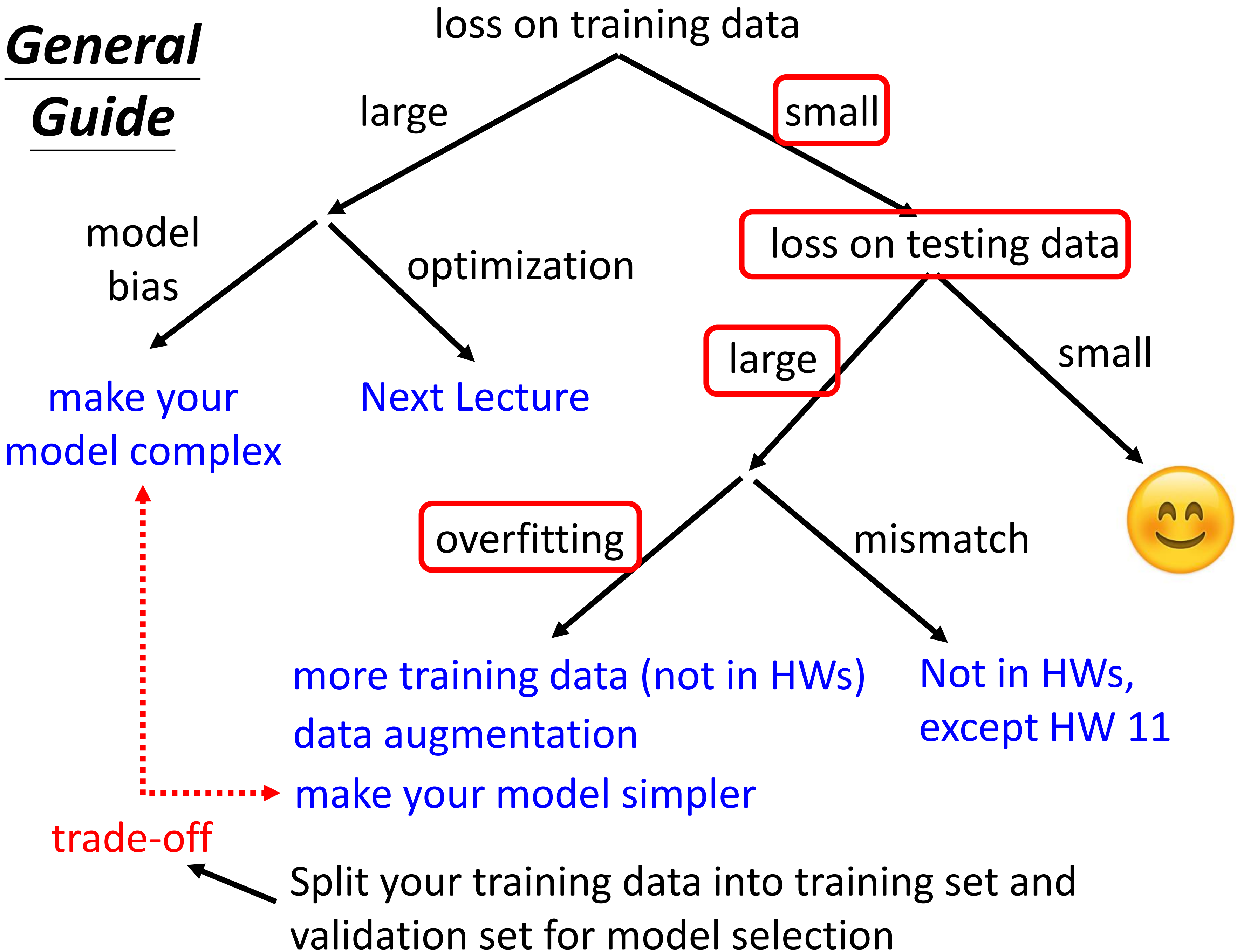
Optimization Issue

- Gaining the insights from comparison
- Start from shallower networks (or other models), which are easier to optimize.
- If deeper networks do not obtain smaller loss on **training data**, then there is optimization issue.

	1 layer	2 layer	3 layer	4 layer	5 layer
2017 – 2020	0.28k	0.18k	0.14k	0.10k	$\boxed{0.34k}$

- Solution: More powerful optimization technology (next lecture)


General Guide
loss on training data
large
small
model bias
optimization
make your model complex
Next Lecture
loss on testing data
large
small
overfitting
mismatch
more training data (not in HWs)
data augmentation
make your model simpler
Not in HWs, except HW 11
trade-off
Split your training data into training set and validation set for model selection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Overfitting

- Small loss on training data, large loss on testing data. Why?

<u>An extreme example</u>

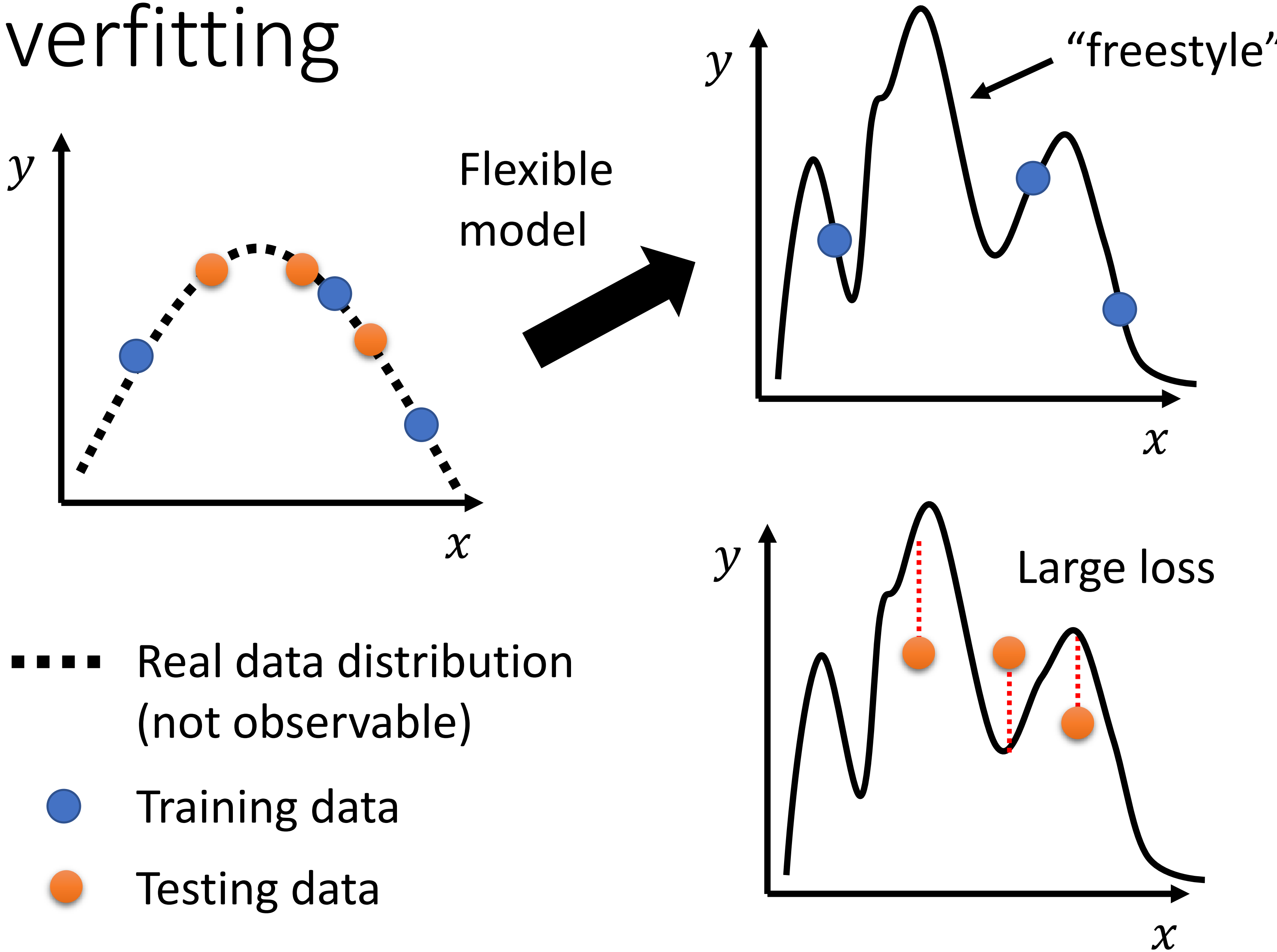
Training data: $\left\{\left(\boldsymbol{x}^{\mathbf{1}}, \hat{y}^{1}\right),\left(\boldsymbol{x}^{\mathbf{2}}, \hat{y}^{2}\right), \ldots,\left(\boldsymbol{x}^{\boldsymbol{N}}, \hat{y}^{N}\right)\right\}$

$$f(\boldsymbol{x})=\begin{cases}\hat{y}^{i} & \exists \boldsymbol{x}^{\boldsymbol{i}}=\boldsymbol{x} \\ random & otherwise\end{cases}$$

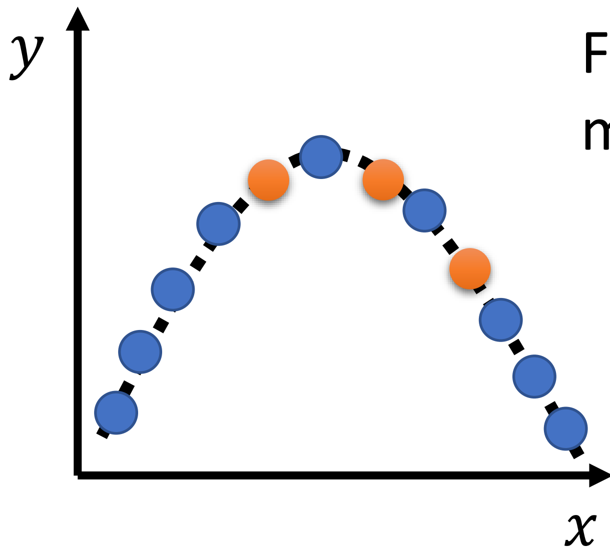
Less than useless …

This function obtains **zero training loss**, but **large testing loss**.

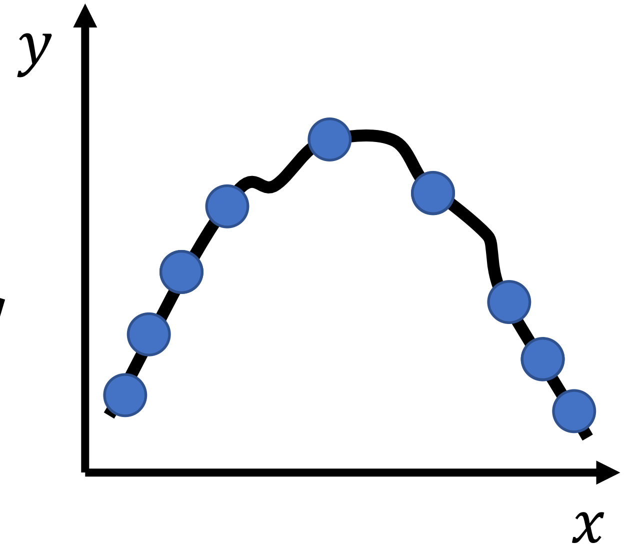
Overfitting



Overfitting



Flexible model

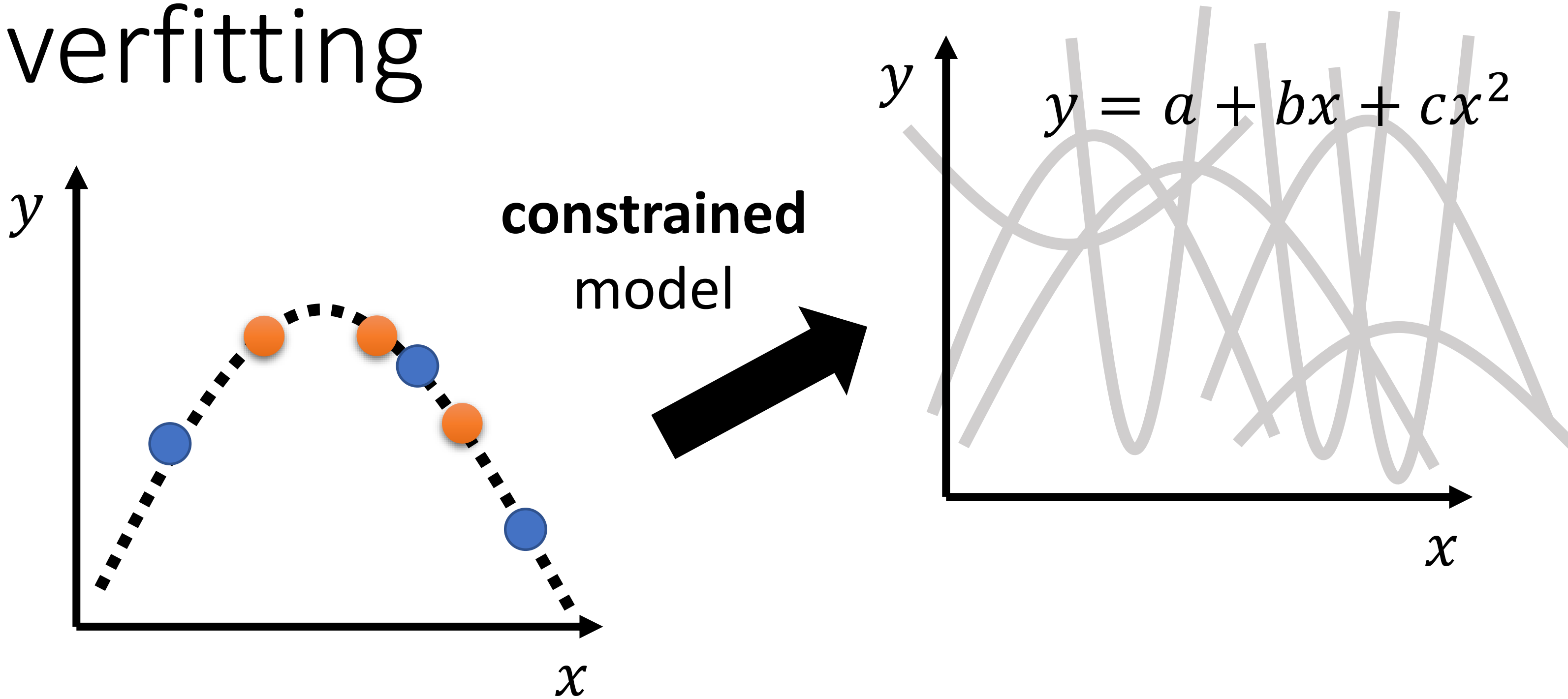


More training data
(cannot do it in HWs)

Data augmentation (you can do that in HWs)




Overfitting

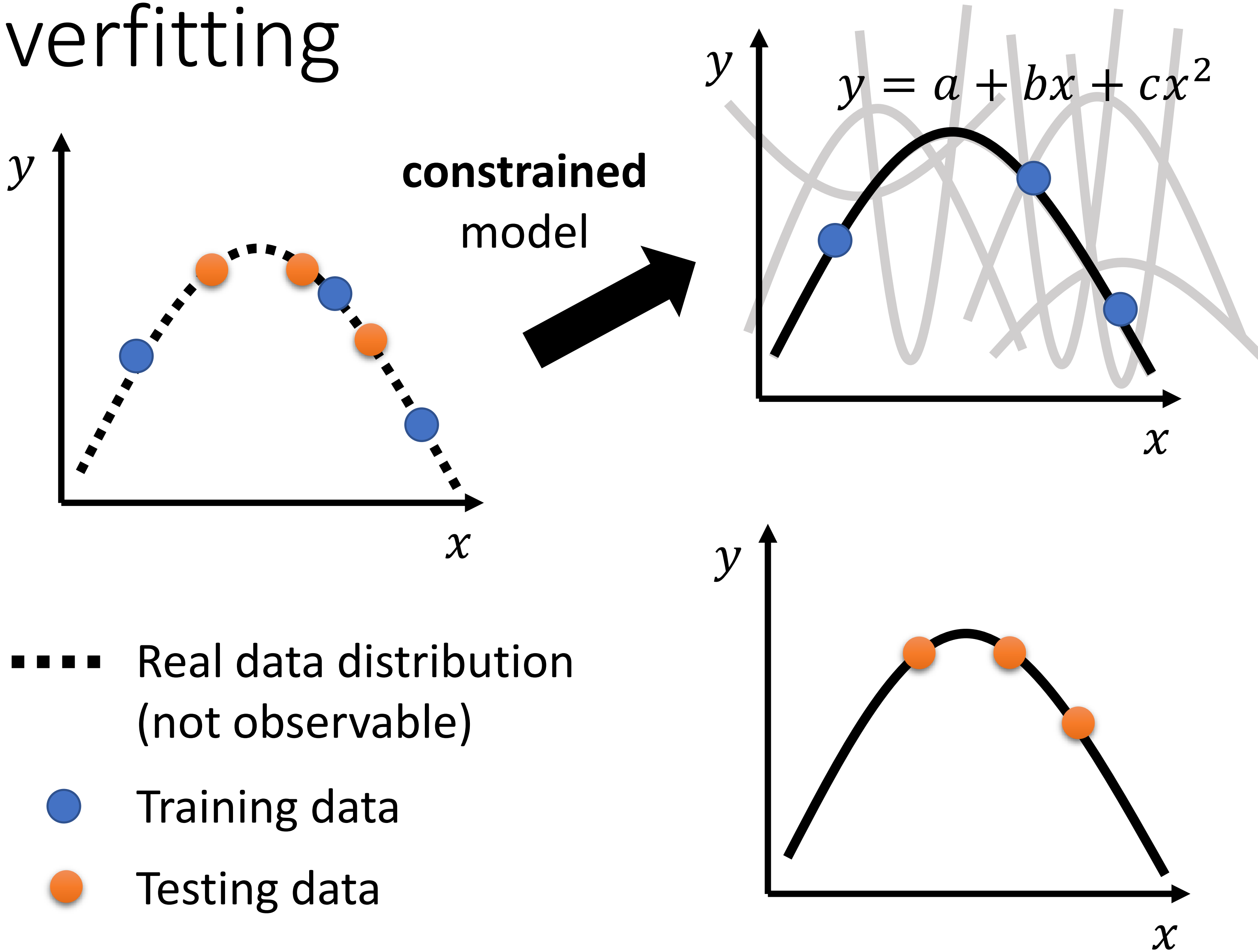


Real data distribution
(not observable)

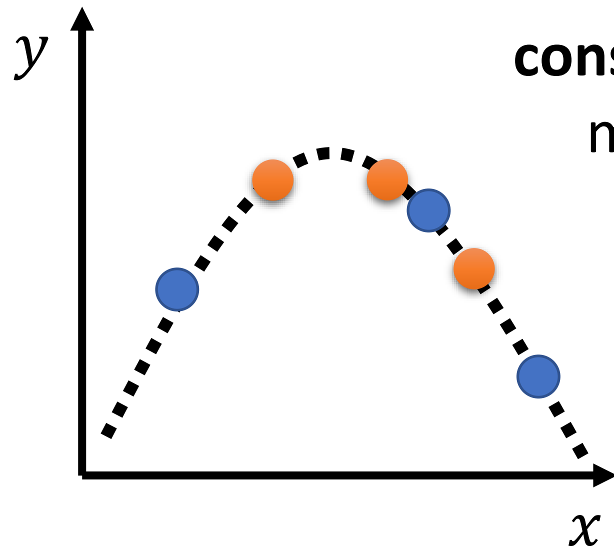
Training data

Testing data

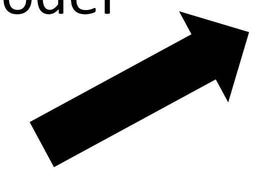
Overfitting

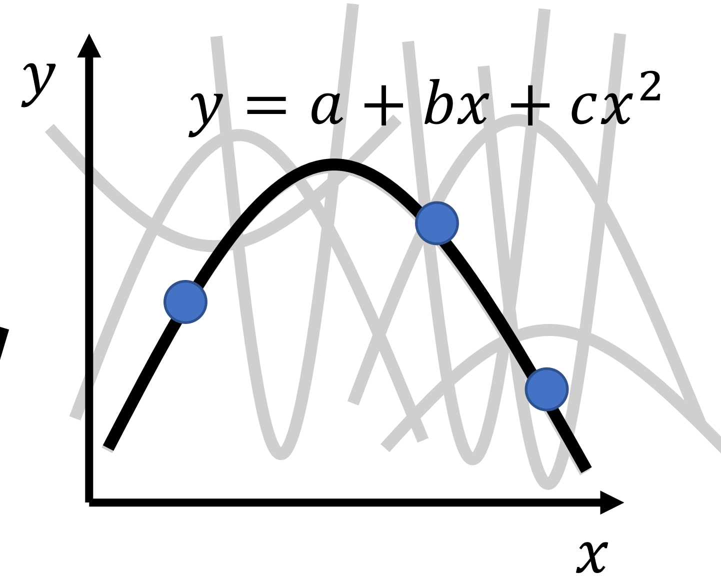


Overfitting

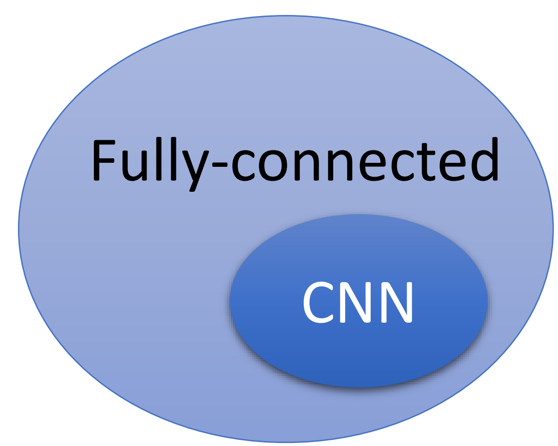


constrained
model

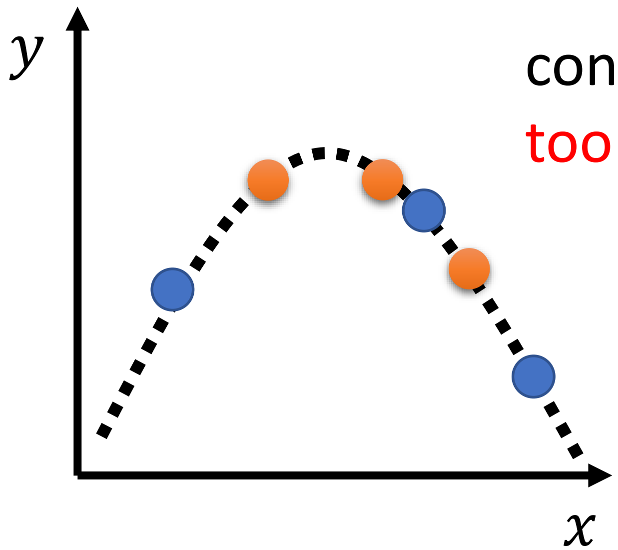




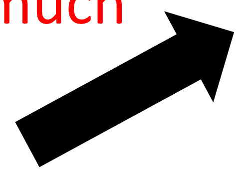
- Less parameters, sharing parameters
- Less features
- Early stopping
- Regularization
- Dropout

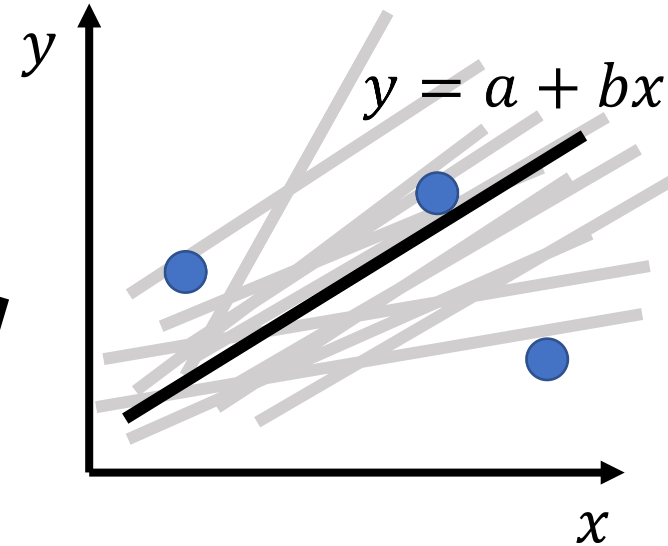


Overfitting

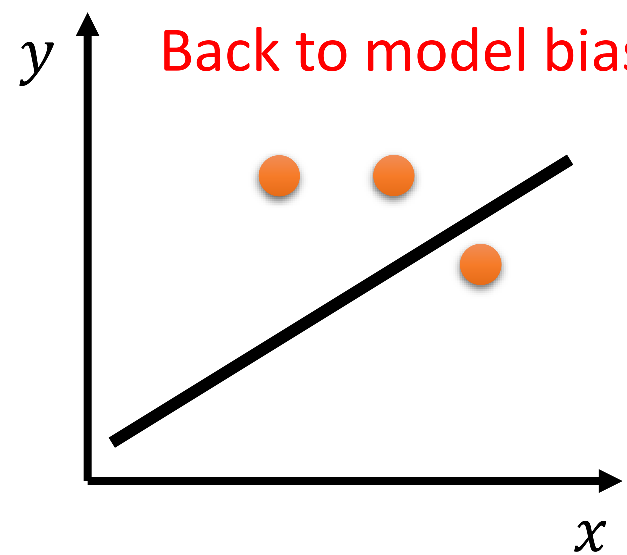


constrain
too much





Back to model bias …

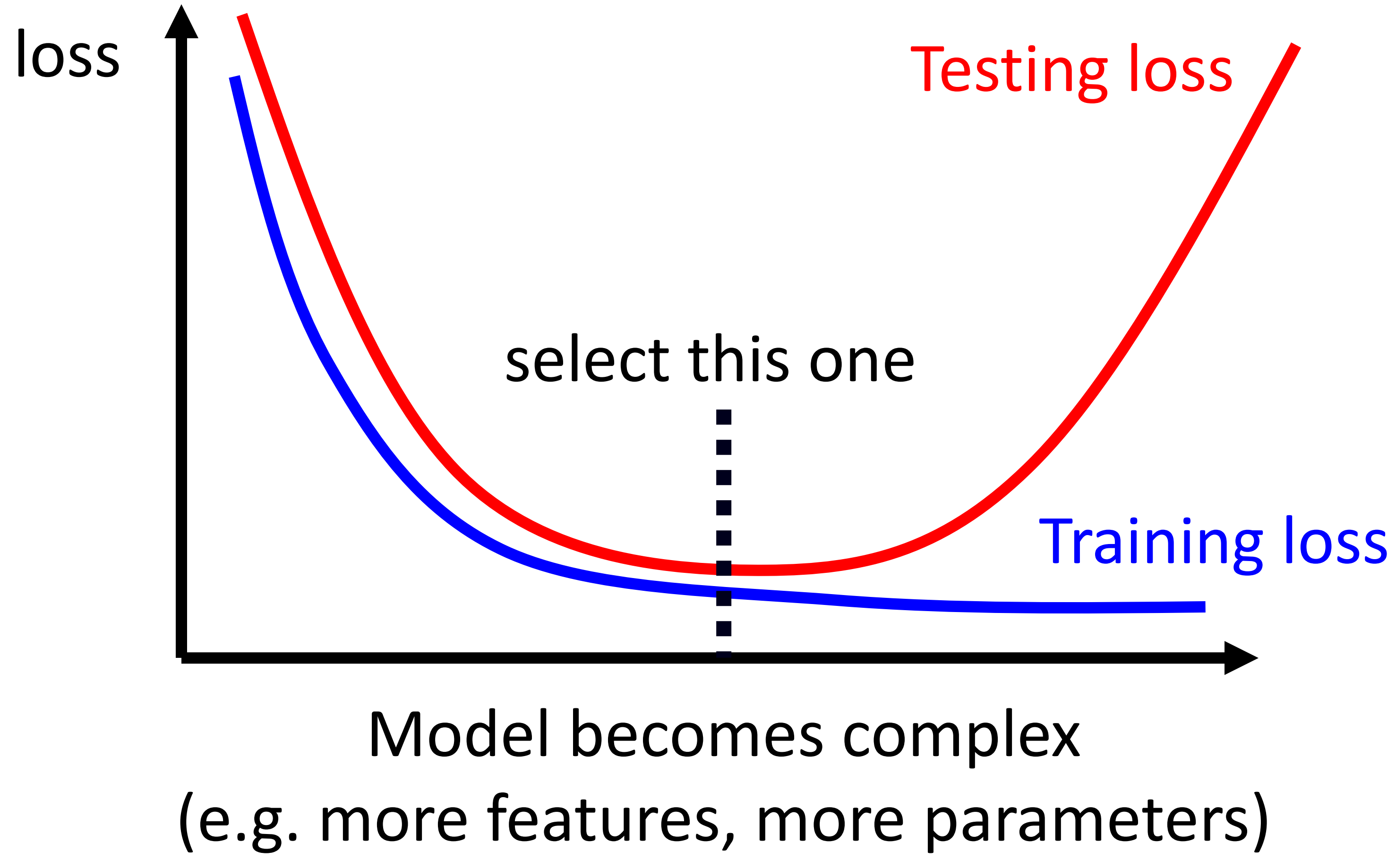


Real data distribution
(not observable)

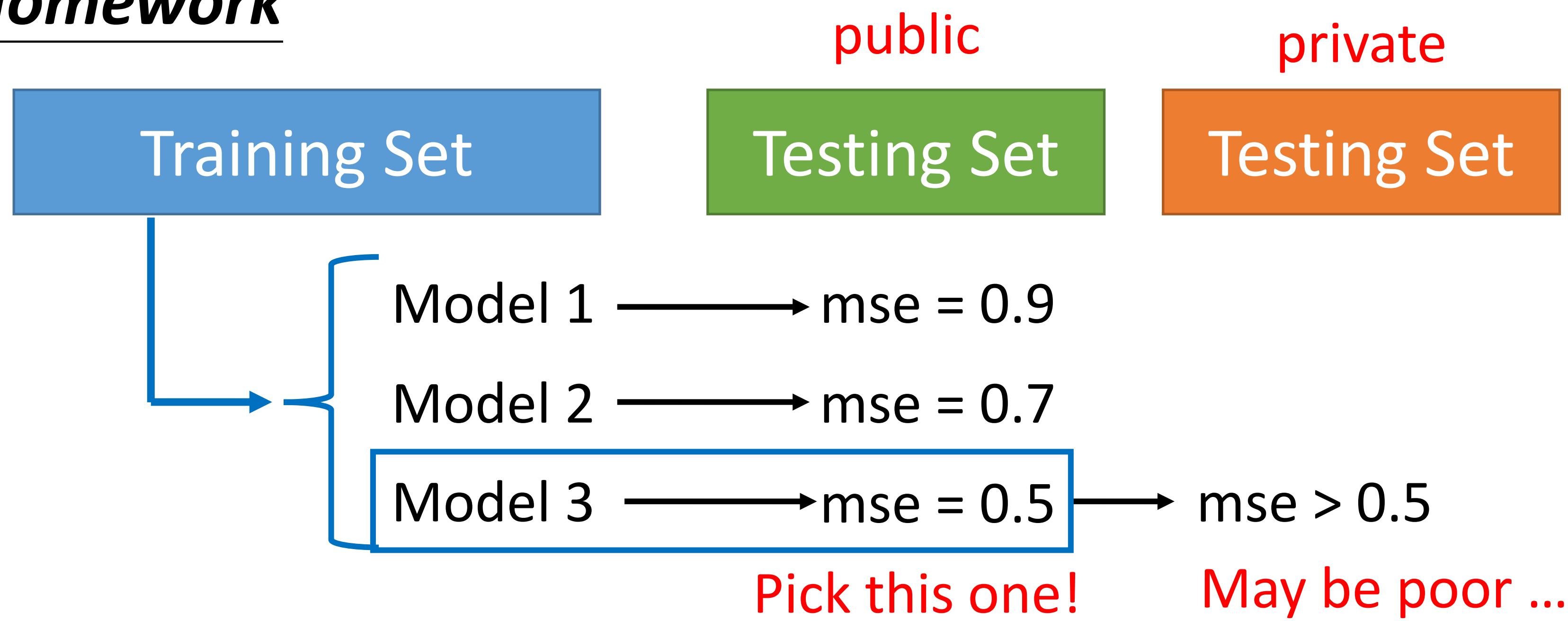
Training data

Testing data

Bias-Complexity Trade-off



Homework



The extreme example again

$$f_k(\boldsymbol{x}) = \begin{cases} \hat{y}^i & \exists \boldsymbol{x}^i = \boldsymbol{x} \\ random & otherwise \end{cases}$$

k: 1 - 1000000000000000000000

It is possible that $f_{56789}(\boldsymbol{x})$ **happens** to get good performance on public testing set.

So you select $f_{56789}(\boldsymbol{x})$ …… Random on private testing set

Homework

public	private

Training Set	Testing Set	Testing Set
	public	private

Why?

Model 1 → mse = 0.9

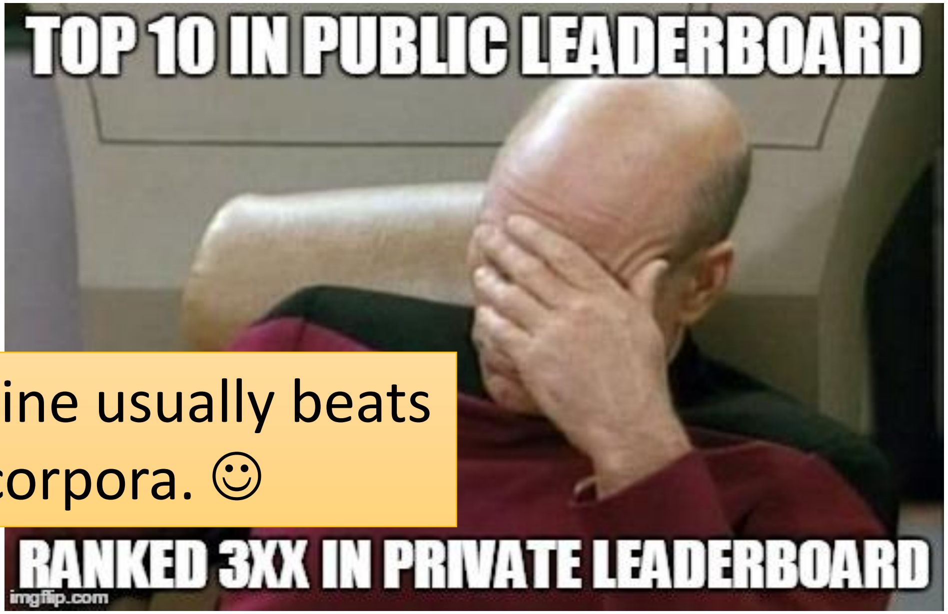
Model 2 → mse = 0.7

$\boxed{\text{Model 3} \rightarrow \text{mse} = 0.5}$ → mse > 0.5

Pick this one! May be poor …

What will happen?

http://www.chioka.in/how-to-select-your-final-models-in-a-kaggle-competitio/



This explains why machine usually beats human on benchmark corpora. ☺

Cross Validation

How to split?

Training Set

Training Set | Validation set

Model 1 → mse = 0.9

Model 2 → mse = 0.7

Model 3 → mse = 0.5 → mse > 0.5 → mse > 0.5

public — Testing Set

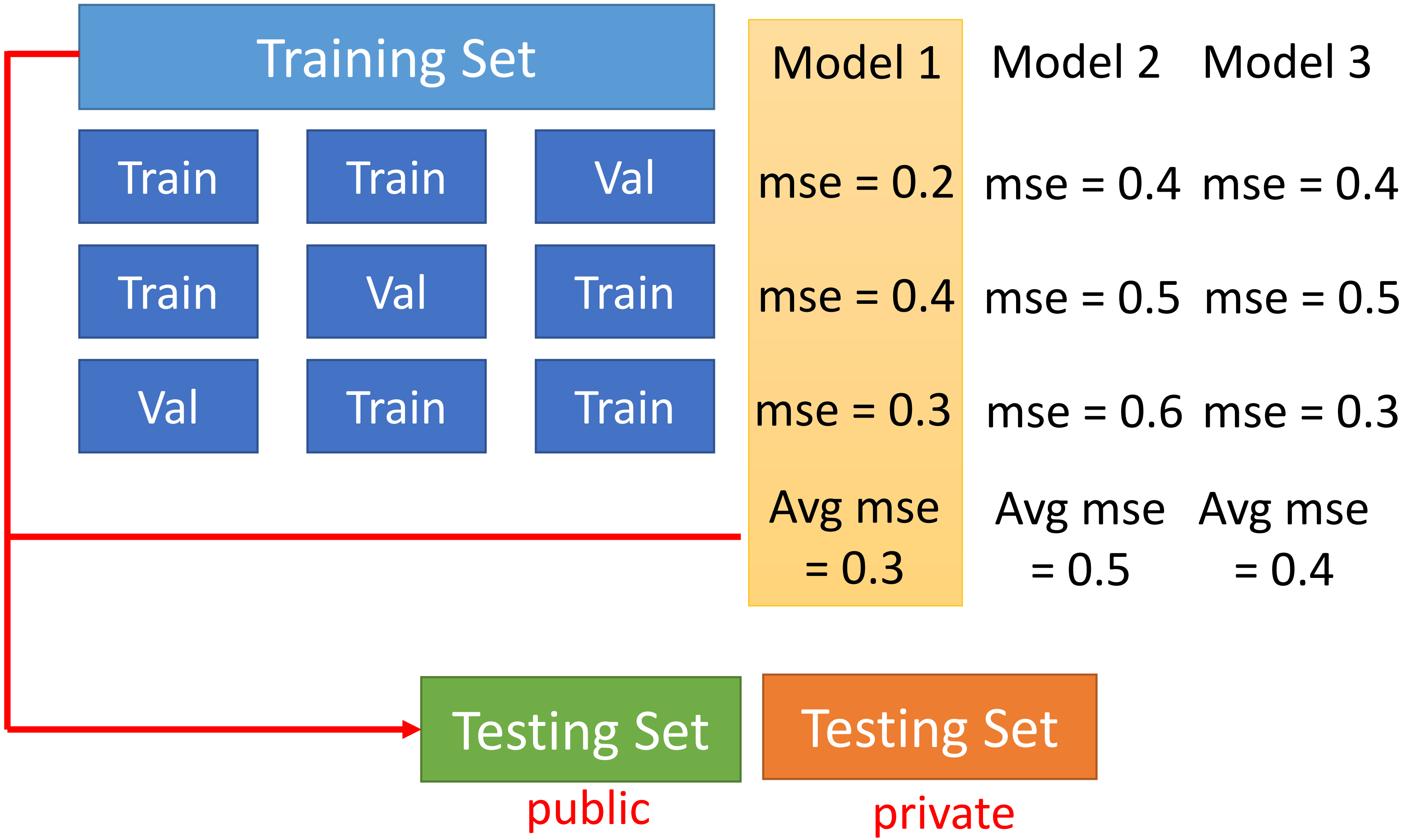
private — Testing Set

Using the results of public testing data to select your model

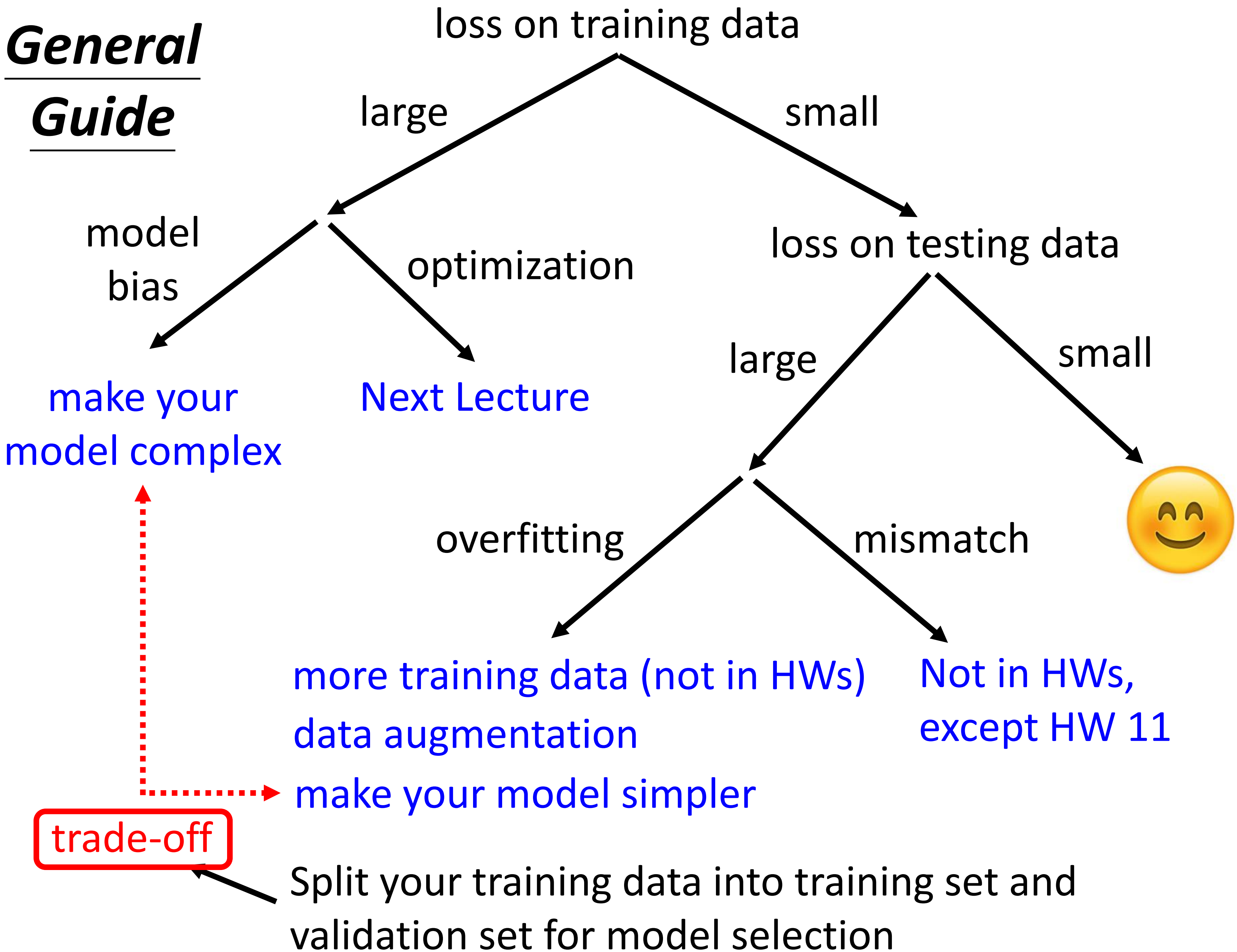
You are making public set better than private set.

Not recommend

N-fold Cross Validation

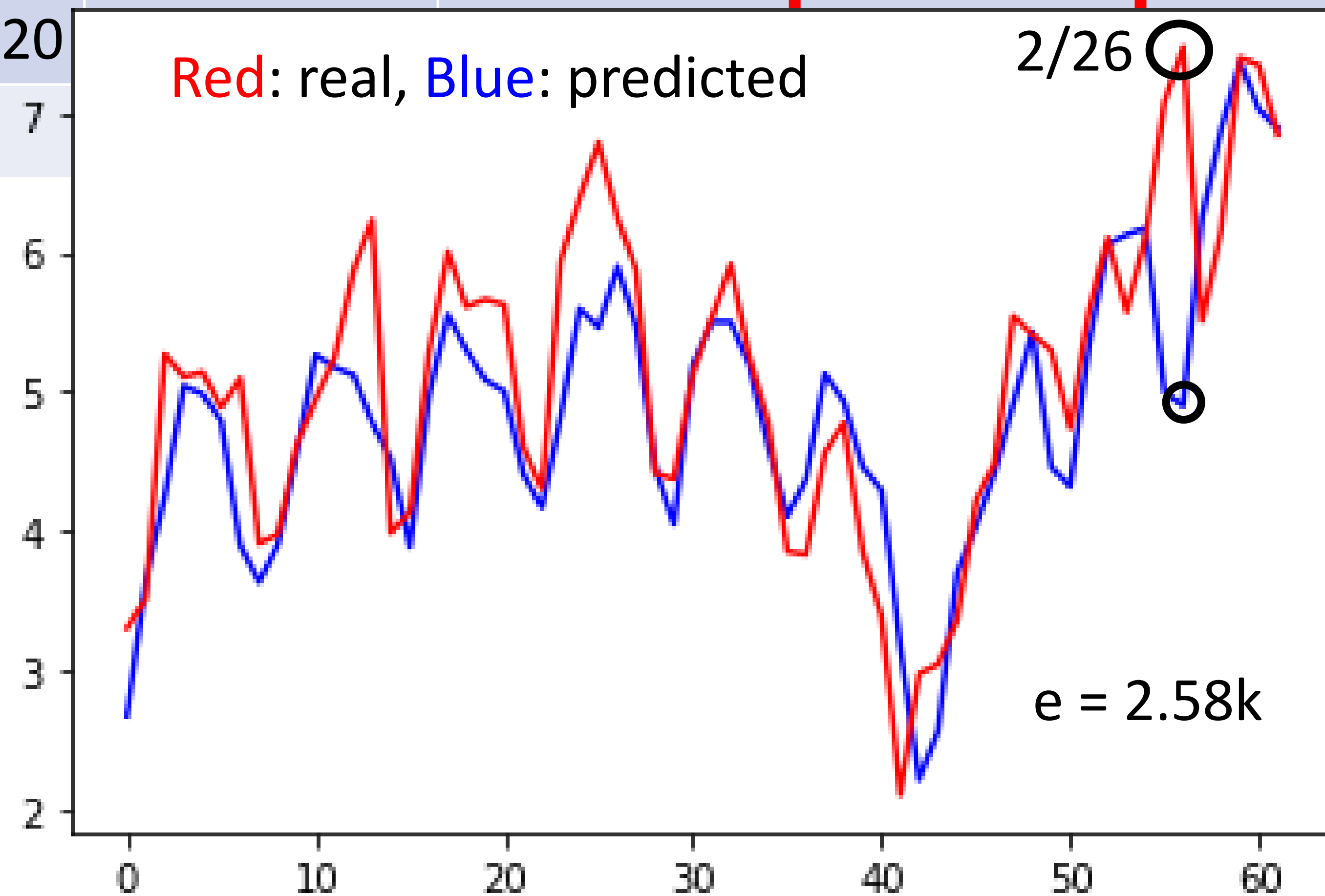


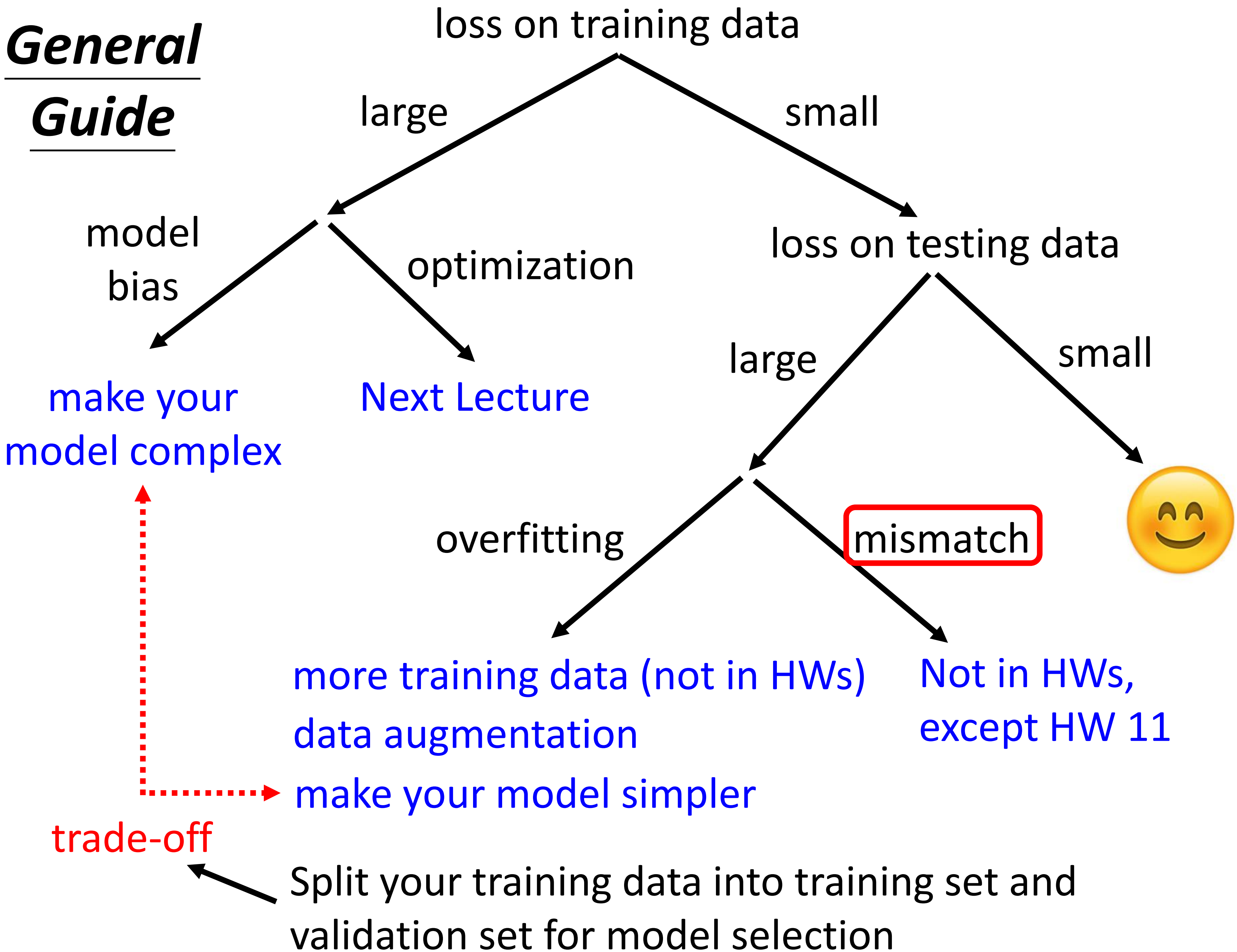
General Guide



Let’s predict no. of views of 2/26!

	1 layer	2 layer	3 layer	4 layer
2017 – 2020				0k
2021				4k

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Mismatch

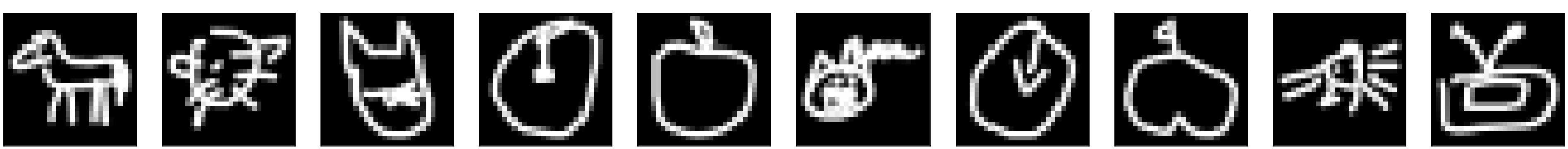
- Your training and testing data have different distributions. Be aware of how data is generated.

<u>Most HWs do not have this problem, except HW11</u>

Training Data

Simply increasing the training data will not help.

Testing Data



General Guide