Introduction to Deep Learning (I2DL)

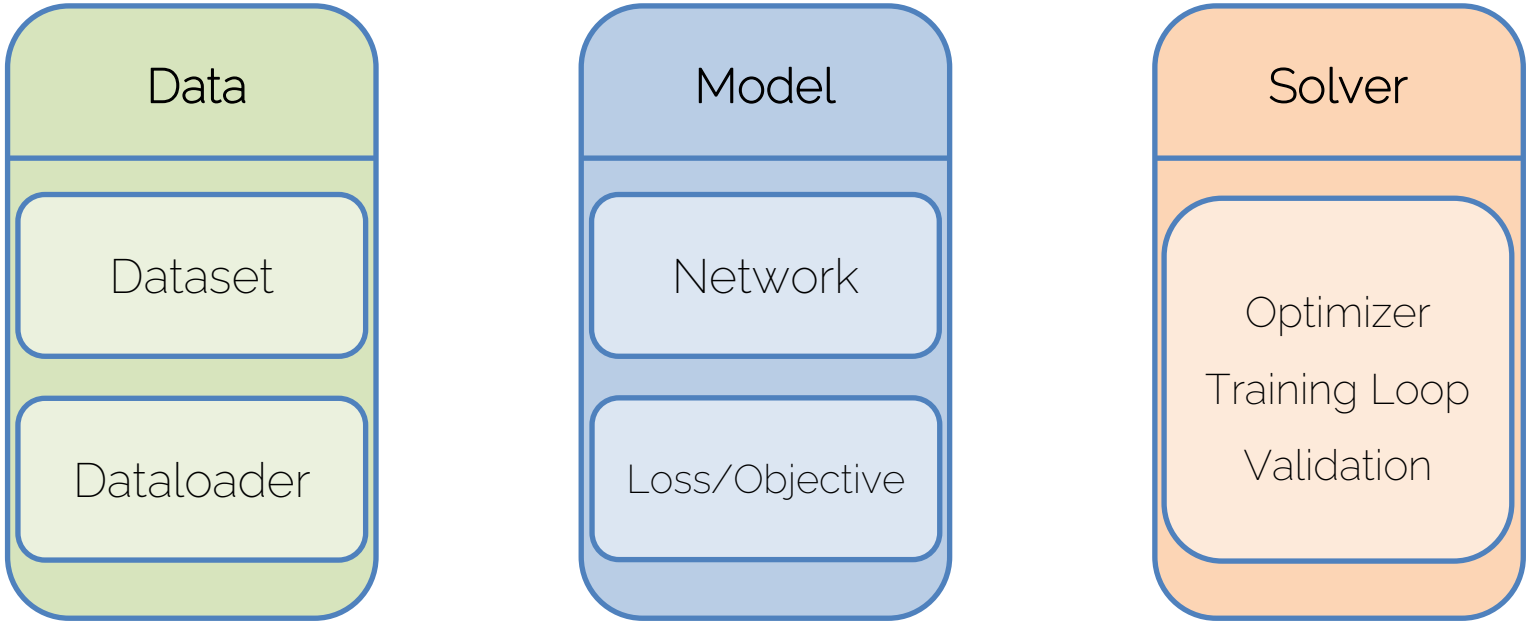
Exercise 4: Simple Classifier

Today's Outline

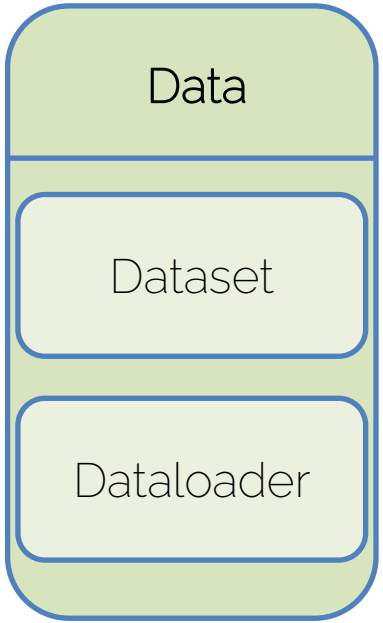
- The Pillars of Deep Learning
- Exercise 4: Simple Classifier → Binary Prediction
  - Housing Dataset
  - Training loop: Forward & Backward pass
- Backpropagation

The Pillars of Deep Learning

The Pillars of Deep Learning



The Pillars of Deep Learning



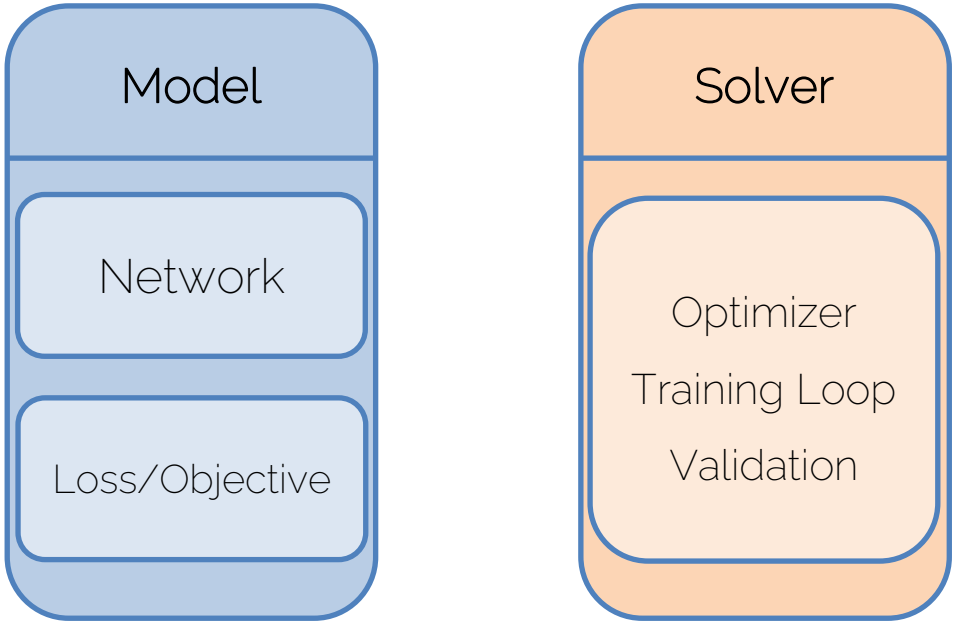
Exercise 3: Dataset and Dataloader

The Pillars of Deep Learning

Exercise 4: Simple Classifier

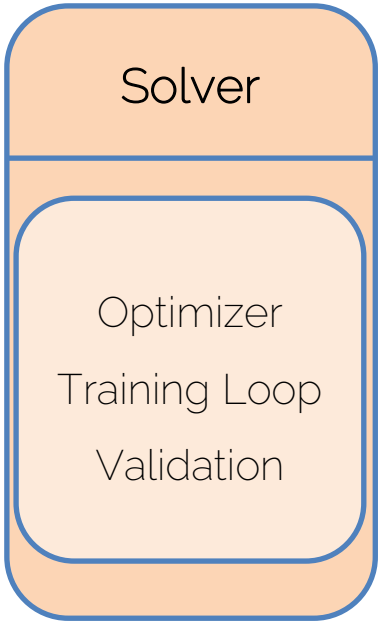
Exercise 5: Simple Network

Exercise 6: Hyperparameter Tuning



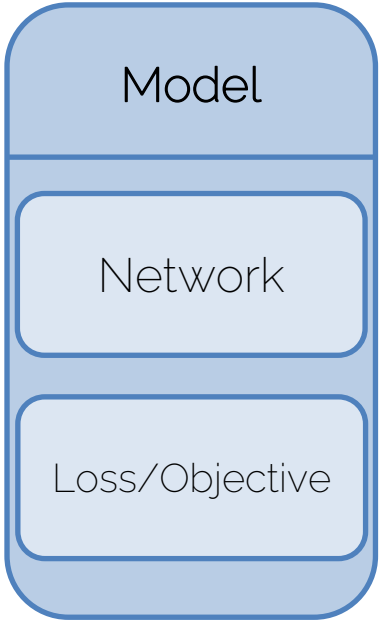
Goal: Exercise 4

- Goal: Training process
- Skip: Model Pillar
- Simplified Model: Classifier which is a 1-Layer Neural Network



Goals: Exercises 5++

- Ex 3 + 4: Dataloading and Trainings process
- Ex 5++: Expand the exercises to more interesting model architectures



Exercise 4: Simple Classifier

Housing Dataset

- **Housing Dataset**: Data of ~1400 houses including 81 features like Neighborhood, GrLivArea, YearBuilt, etc.

- **Simplified model**: 1 input feature to predict house price label ("expensive" vs "low-prized")

housing_train

Id	Neighborhood	BldgType	HouseStyle	YearBuilt	YearRemodAdd	RoofStyle	CentralAir	GrLivArea	FullBath	HalfBath	Fireplaces	PoolArea	Fence	SalePrice
1	CollgCr	1Fam	2Story	2003	2003	Gable	Y	1710	2	1	0	0	NA	208500
2	Veenker	1Fam	1Story	1976	1976	Gable	Y	1262	2	0	1	0	NA	181500
3	CollgCr	1Fam	2Story	2001	2002	Gable	Y	1786	2	1	1	0	NA	223500
4	Crawfor	1Fam	2Story	1915	1970	Gable	Y	1717	1	0	1	0	NA	140000
5	NoRidge	1Fam	2Story	2000	2000	Gable	Y	2198	2	1	1	0	NA	250000
6	Mitchel	1Fam	1.5Fin	1993	1995	Gable	Y	1362	1	1	0	0	MnPrv	143000
7	Somerst	1Fam	1Story	2004	2005	Gable	Y	1694	2	0	1	0	NA	307000
8	NWAmes	1Fam	2Story	1973	1973	Gable	Y	2090	2	1	2	0	NA	200000

Exercise 4 - Classifying House Prices

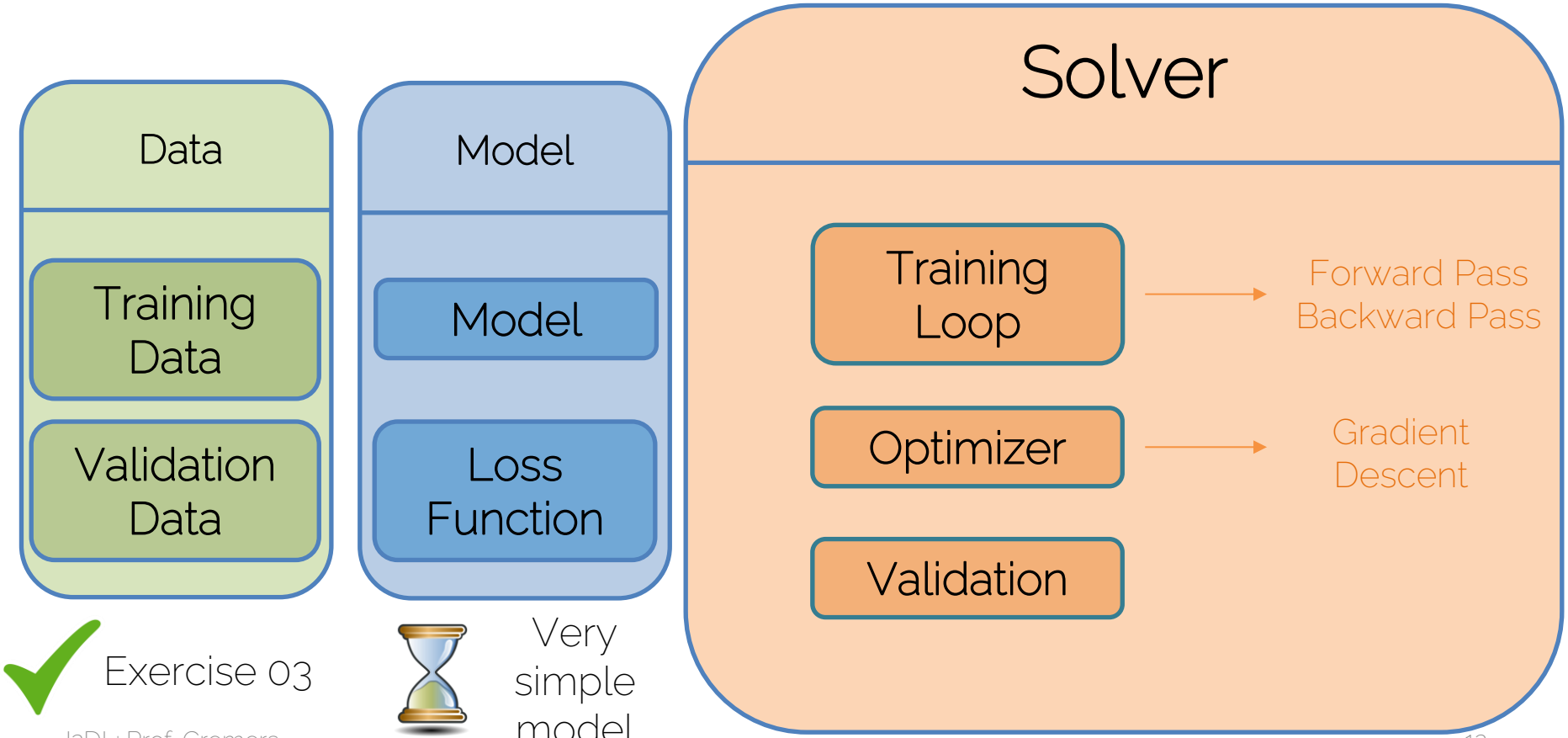
ML Model M
$M(\mathbf{x}) = \mathbf{y}$

Expensive $y = 1$

ML Model M
$M(\mathbf{x}) = \mathbf{y}$

Low-priced $y = 0$

3rd Pillar of Deep Learning



Exercise 03

Very simple model

Backpropagation

Backpropagation: Overview

Forward pass

$\mathrm{M}_\theta(\mathrm{x}) = \hat{y}$

$\mathrm{d}\hat{y}/\mathrm{d}\theta$

$\hat{y}$

$\mathrm{L}(y, \hat{y})$

$\mathrm{d}L/\mathrm{d}\hat{y}$

L

$\mathbf{x}$

Input

Prediction

Loss

Backward pass

Backpropagation: Loss Function

Forward pass

$\mathrm{M}_\theta(\mathrm{x}) = \hat{y}$

$\mathrm{d}\hat{y}/\mathrm{d}\theta$

$\hat{y}$

$\mathrm{L}(y, \hat{y})$

$\mathrm{d}L/\mathrm{d}\hat{y}$

L

x

Backward pass

Binary Cross Entropy Loss: $L(y, \hat{y}) = -\left(y \cdot \log(\hat{y}) + (1 - y) \cdot \log(1 - \hat{y})\right)$

Backpropagation: Update Step

Forward pass

$\mathrm{M}_\theta(\mathrm{x}) = \hat{y}$

$\mathrm{d}\hat{y}/\mathrm{d}\theta$

$\hat{y}$

$\mathrm{L}(y, \hat{y})$

$\mathrm{d}L/\mathrm{d}\hat{y}$

L

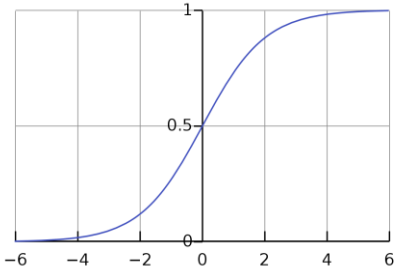
x

Backward pass

Optimization with gradient descent: $\theta_{t+1} = \theta_t - \lambda \cdot \nabla_\theta \mathrm{L}$

Backpropagation: Summary

- Input: $X \in \mathbb{R}^{N \times D+1}$ representing our data with N samples and D+1 feature dimensions
- Output: Binary labels given by $y \in \mathbb{R}^{N \times 1}$
- Model: Classifier of the form $y = \sigma(X \cdot w)$
- Sigmoid function: $\sigma : \mathbb{R} \rightarrow [0, 1]$ with $\sigma(t) = \frac{1}{1+e^{-t}}$



σ Function

- Weights of the Classifier: $w = (w_1, w_2, \ldots, w_{D+1})\top \in \mathbb{R}^{D+1}$

Backpropagation: Example

Backpropagation

Forward pass

x

$\mathrm{M}_\theta(\mathrm{x}) = \hat{y}$

$\mathrm{d}\hat{y}/\mathrm{d}\theta$

$\hat{y}$

$\mathrm{L}(y, \hat{y})$

$\mathrm{d}L/\mathrm{d}\hat{y}$

L

Backward pass

Forward Pass

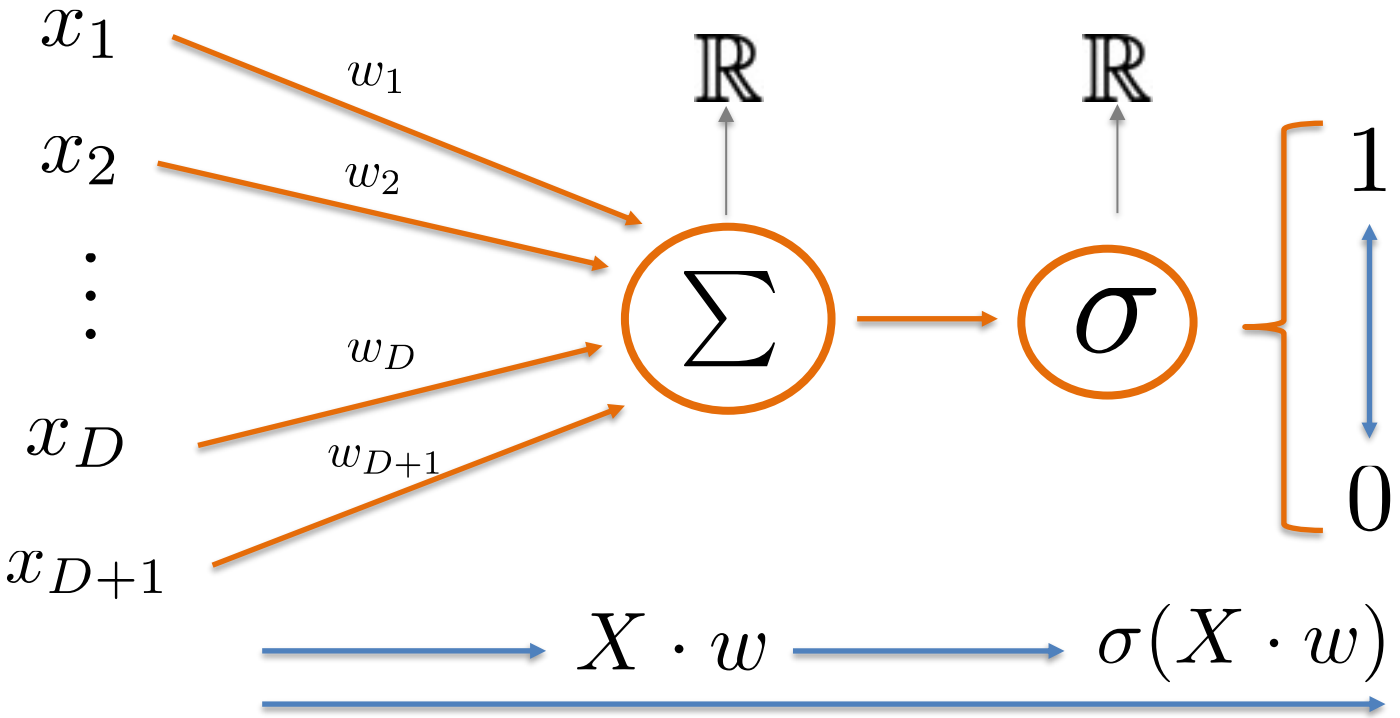
(Single sample)

Sample

$x = (x_1, x_2, \ldots, x_{D+1})$

Classifier Model

$y = \sigma(X \cdot w)$



Input Data X

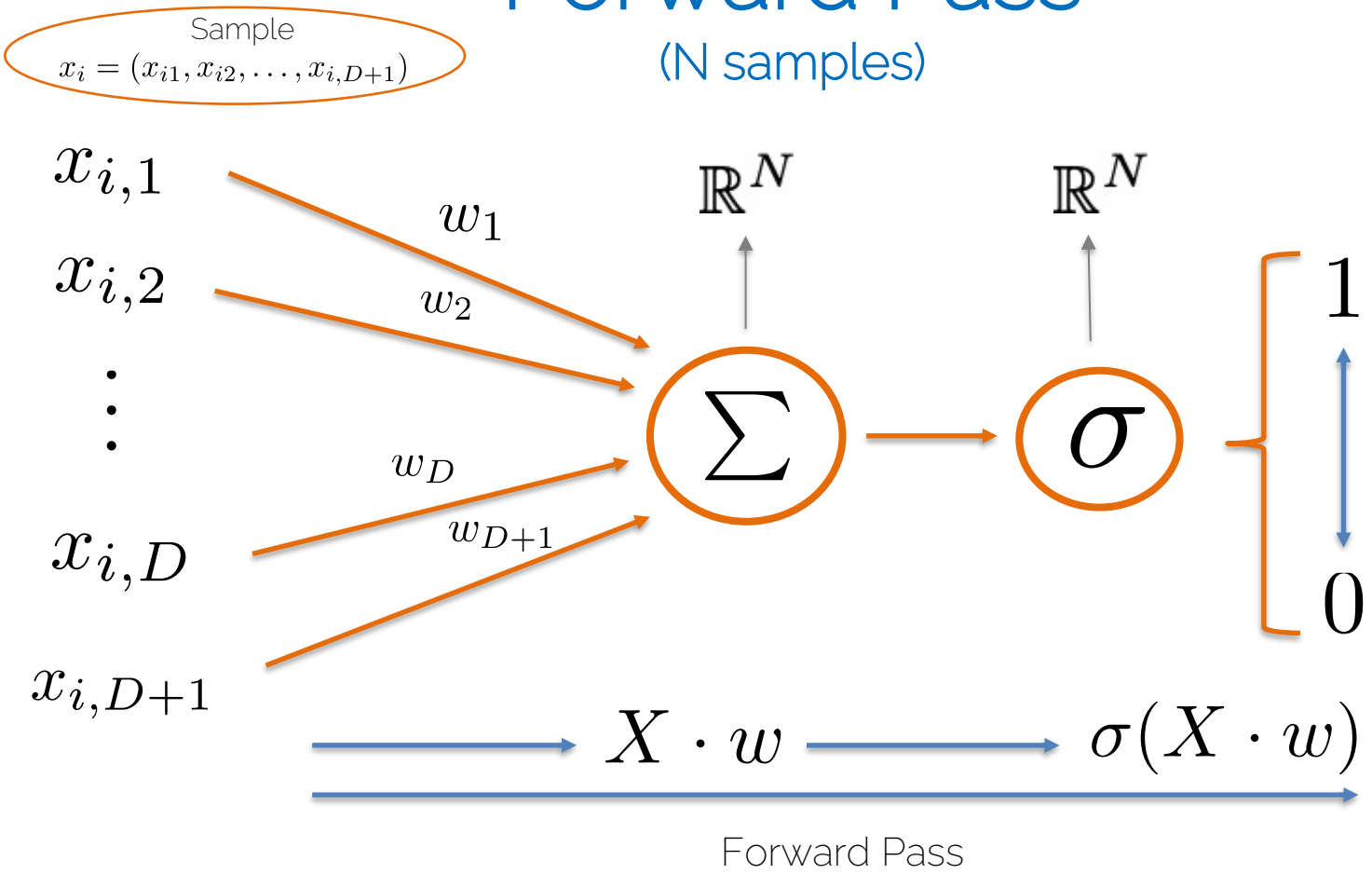
(Single sample -> N samples)

$$X \in \mathbb{R}^{N \times D+1}$$

$$X = \begin{pmatrix} x_{1,1} & x_{1,2} & \dots & x_{1,D+1} \\ x_{2,1} & x_{2,2} & \dots & x_{2,D+1} \\ \vdots & \vdots & \ddots & \vdots \\ x_{N,1} & x_{N,2} & \dots & x_{N,D+1} \end{pmatrix}$$

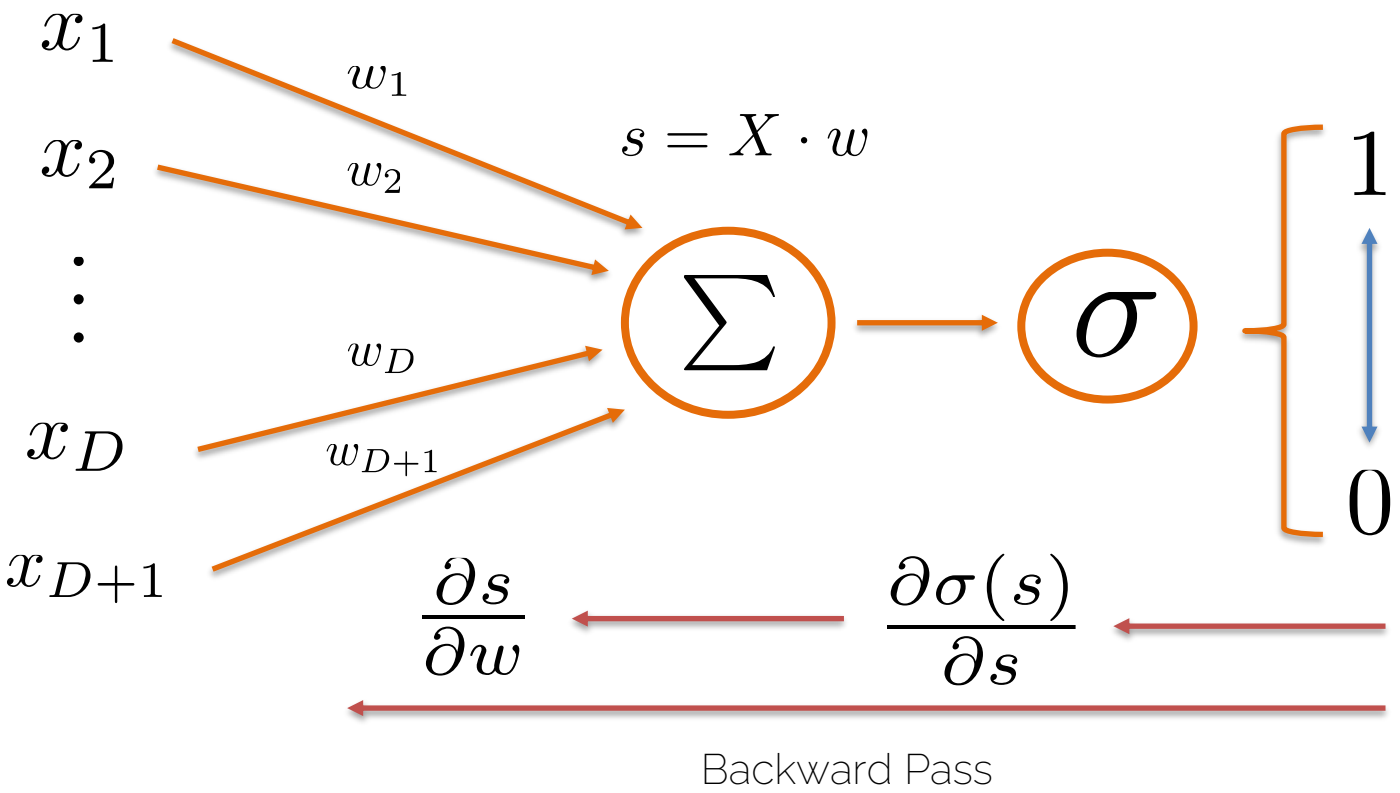
Forward Pass

(N samples)



Backward Pass

Sample
$x = (x_1, x_2, \ldots, x_{D+1})$



Backward Pass

- **Backward Pass:** Derivative of function with respect to weights $w = (w_1, w_2, \ldots, w_{D+1})$ of our Classifier
- **Attention:** Make sure you understand the dimensions here
- **Step 1:** Forward + Backward Pass for one sample
- **Step 2:** Forward + Backward Pass for N samples

Overview Exercise 4

- Two Notebooks
  - Optional: Preprocessing
  - Logistic regression model

Fixed Deadline:
Wednesday 15:59

- Submission
  - Several implementation tasks in the notebook
  - Submission file creation in Notebook

See you next week ☺