

Introduction to Deep Learning (I2DL)

Exercise 4: Linear and logistic regression

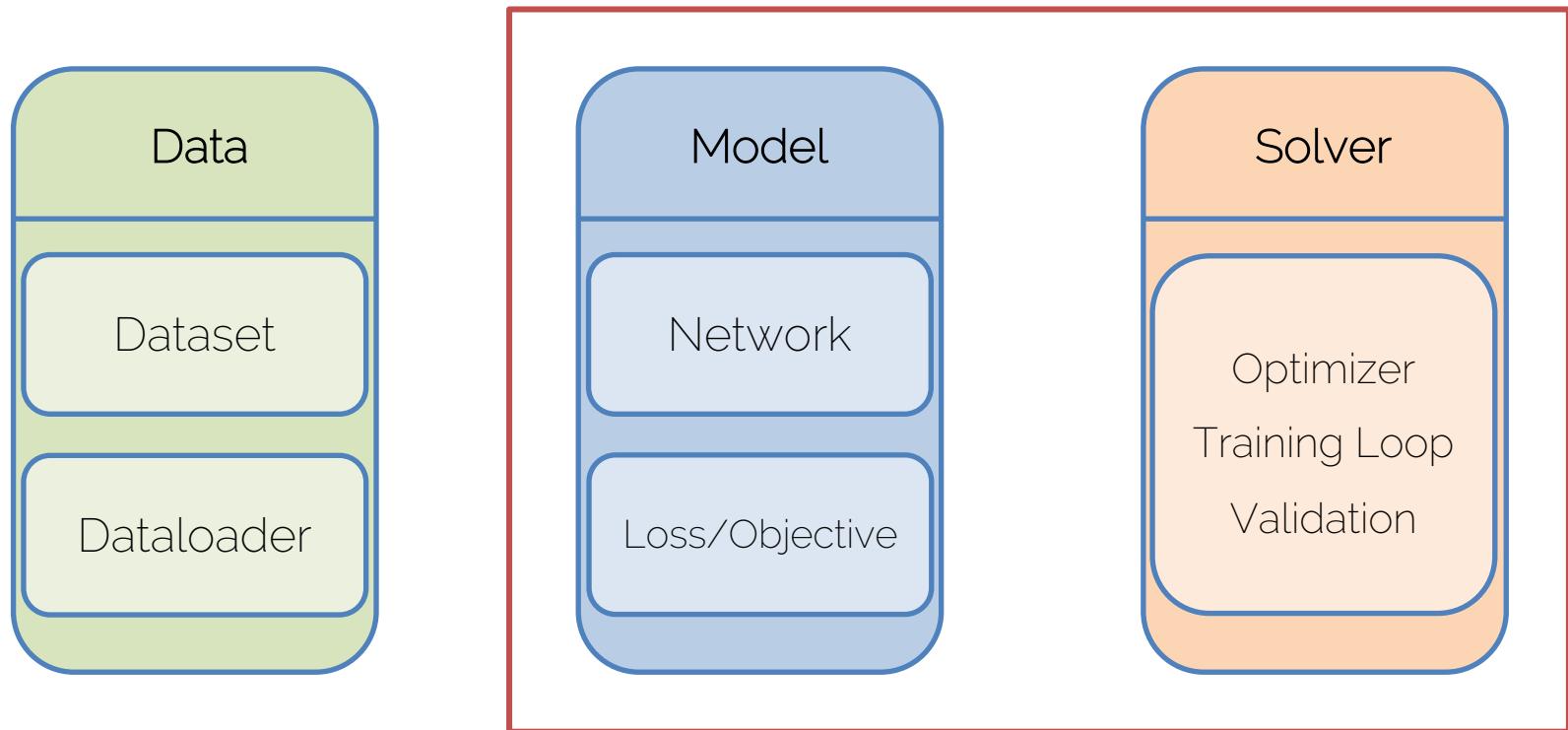
Today's Outline

- Submission System
- Linear Regression
 - Model
 - Loss Function
 - Optimization (Gradient Descent)
 - Solver
- Submission 4: Logistic Regression
 - Start: May 14, 2020 12.00
 - End: May 20, 2020 23.59

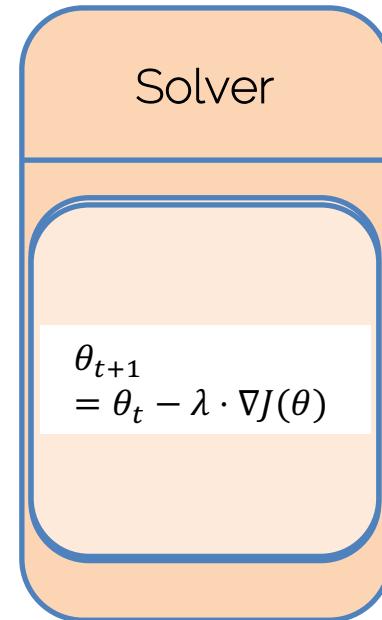
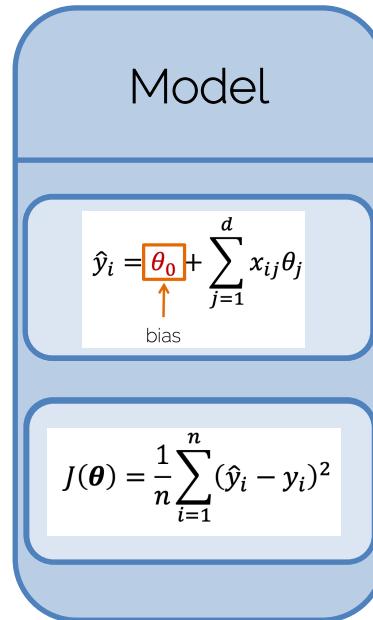
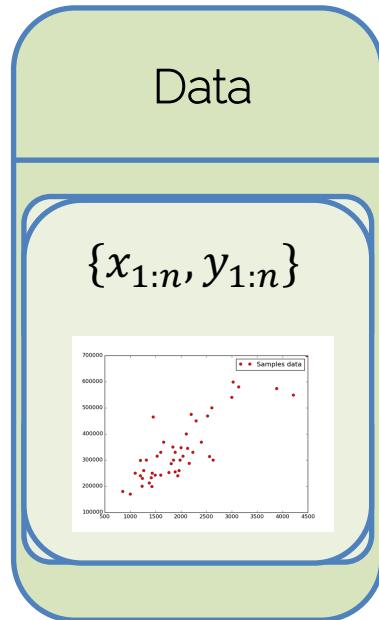
Submission Rules

- Submission Regulations:
 - No submission after deadline
 - Submission Limit: max. 5 successful submissions

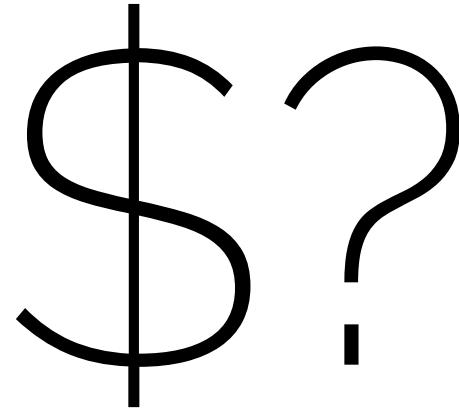
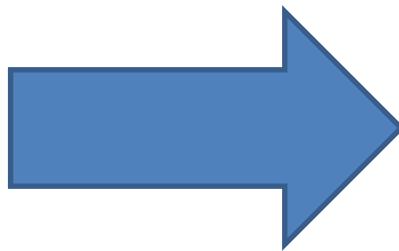
The Pillars of Deep Learning



The Pillars of Deep Learning



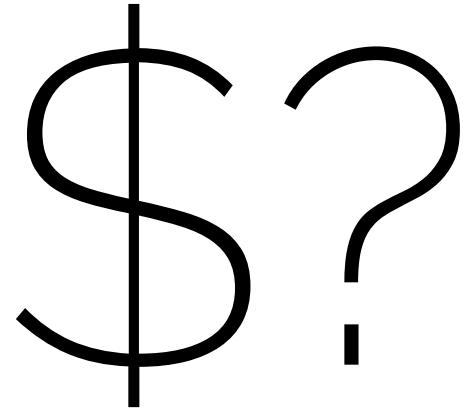
Linear Regression for House Prices



Linear Regression for House Prices

$\begin{pmatrix} \text{LivingArea} \\ \text{YearBuilt} \\ \text{OutdoorArea} \\ \dots \end{pmatrix}$

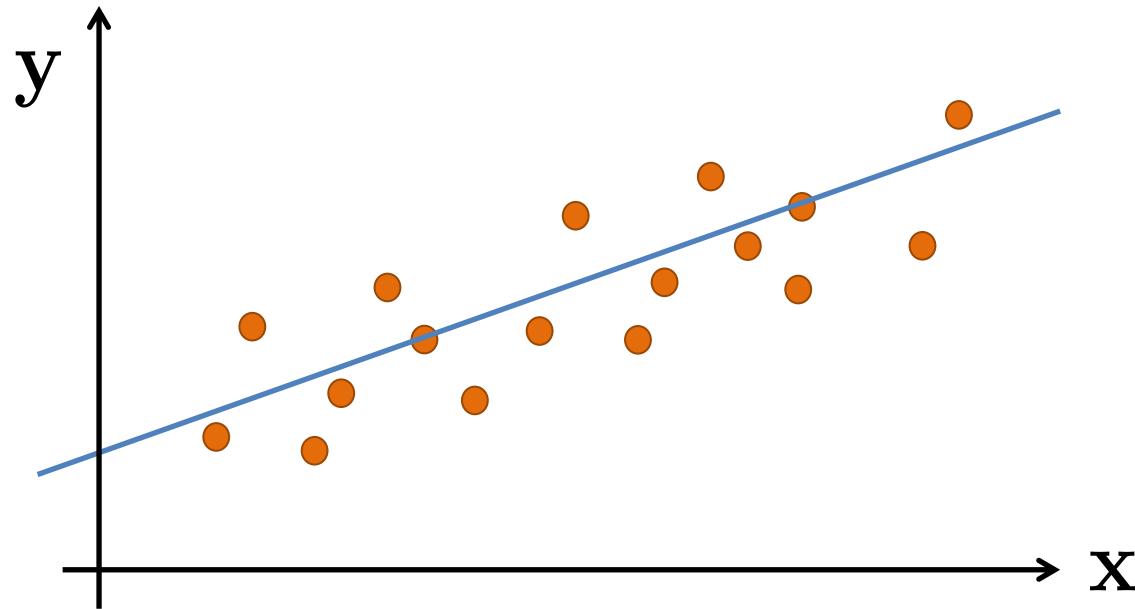
ML Model M
 $M(x) = y$



\$?

Linear Regression for House Prices

- Find a linear model that explains a target y given the inputs X



Linear Regression for House Prices

- A linear model is expressed in the form

$$\hat{y}_i = \theta_0 + \sum_{j=1}^d x_{ij} \theta_j$$

Bias, model parameters

Input dimension

Weights, model parameters

Input data, features

The diagram illustrates the components of a linear regression equation. The equation itself is $\hat{y}_i = \theta_0 + \sum_{j=1}^d x_{ij} \theta_j$. Several annotations provide context for each part:

- A yellow arrow points to the term θ_0 , which is highlighted in yellow, labeled "Bias, model parameters".
- A purple arrow points to the variable d , which is highlighted in purple, labeled "Input dimension".
- A blue arrow points to the term θ_j , which is highlighted in blue, labeled "Weights, model parameters".
- An orange arrow points to the term x_{ij} , which is highlighted in orange, labeled "Input data, features".

Linear Regression for House Prices

Matrix Notation: $\hat{y} = X\theta$

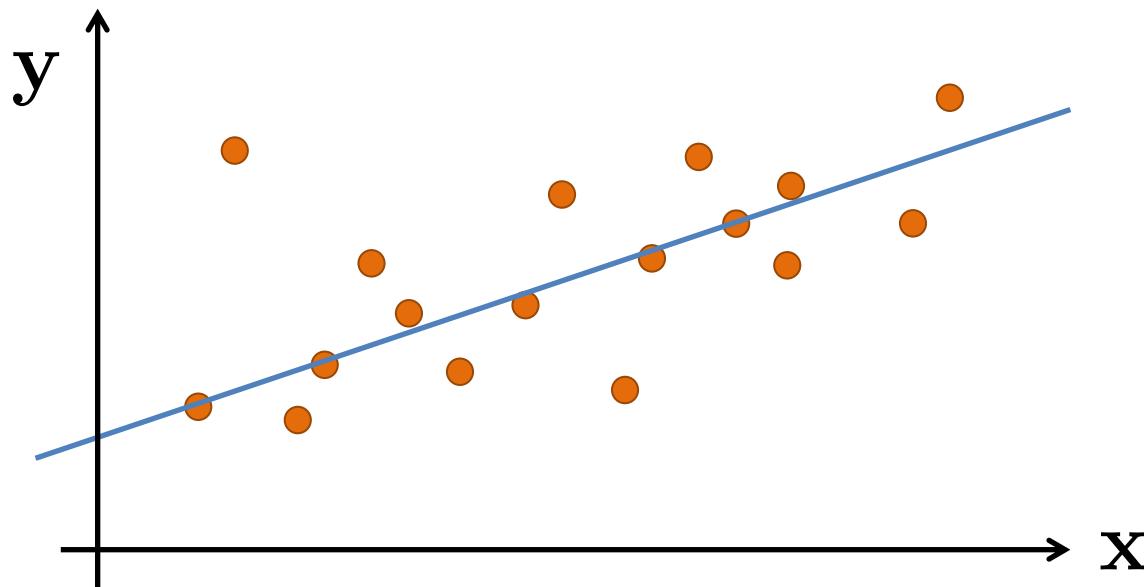
Prediction

Input features

Model parameters

$$\begin{bmatrix} \hat{y}_1 \\ \hat{y}_2 \\ \vdots \\ \hat{y}_n \end{bmatrix} = \begin{bmatrix} 1 & \dots & \hat{x}_{1d} \\ 1 & \dots & \hat{x}_{2d} \\ \vdots & \ddots & \vdots \\ 1 & \dots & \hat{x}_{nd} \end{bmatrix} \begin{bmatrix} \theta_0 \\ \theta_1 \\ \vdots \\ \theta_d \end{bmatrix}$$

Linear regression: loss function



Minimizing

$$J(\boldsymbol{\theta}) = \frac{1}{n} \sum_{i=1}^n (\hat{y}_i - y_i)^2$$

Objective function
Energy
Cost function

Solution for Linear Regression

Analytic

$$\boldsymbol{\theta} = (\mathbf{X}^T \mathbf{X})^{-1} \mathbf{X}^T \mathbf{y}$$

Derivation in additional exercise slides

Numeric

Gradient Descent

$$\boldsymbol{\theta}_{t+1} = \boldsymbol{\theta}_t - \lambda \cdot \nabla_{\boldsymbol{\theta}} J(\boldsymbol{\theta})$$

Solution for Linear Regression

Forward pass



\mathbf{x}

$$\begin{array}{c} M_{\theta}(\mathbf{x}) = \hat{y} \\ \text{d}\hat{y}/\text{d}\theta \end{array}$$

$$\begin{array}{c} \$ \\ \hat{y} \end{array}$$

\$

$$\begin{array}{c} J(y, \hat{y}) \\ \text{d}L/\text{d}\hat{y} \end{array}$$

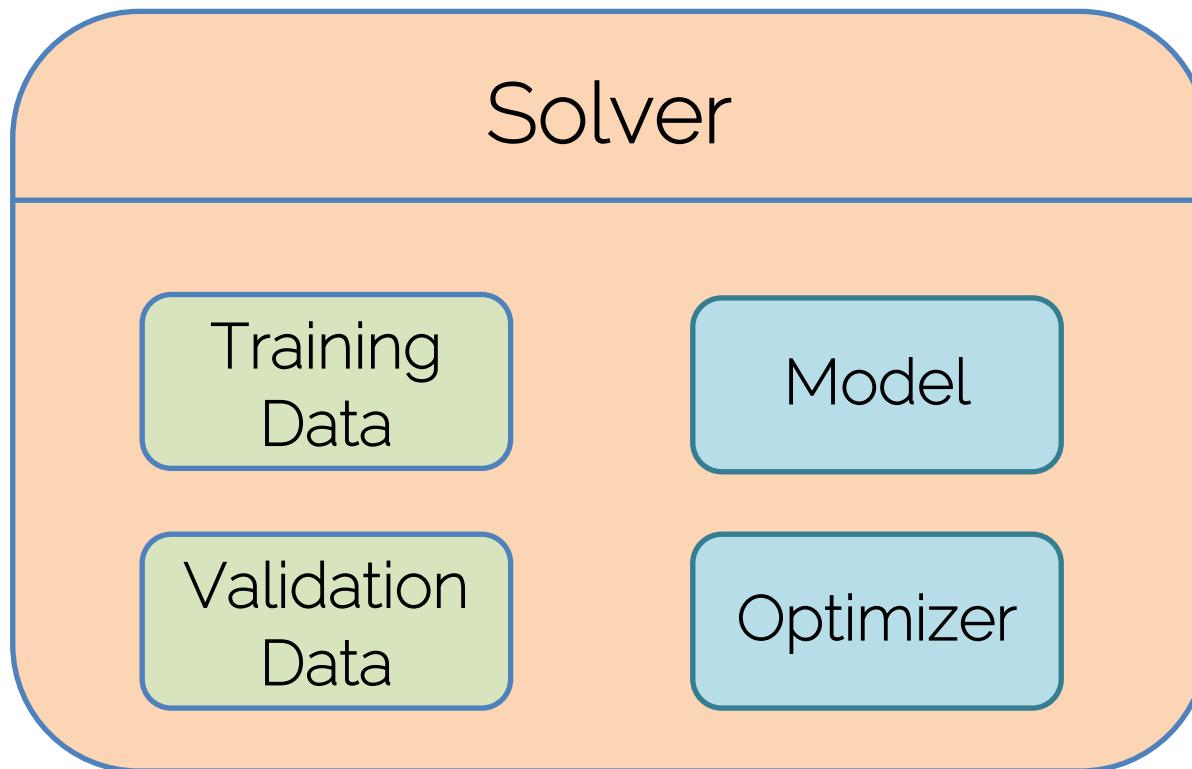
L

Backward pass

Optimization with gradient descent:

$$\theta_{t+1} = \theta_t - \lambda \cdot \nabla_{\theta} L$$

Solution for Linear Regression



Submission 4 - Classifying House Prices



ML Model M
 $M(x) = y$

Expensive $y = 1$



ML Model M
 $M(x) = y$

Low-priced $y = 0$

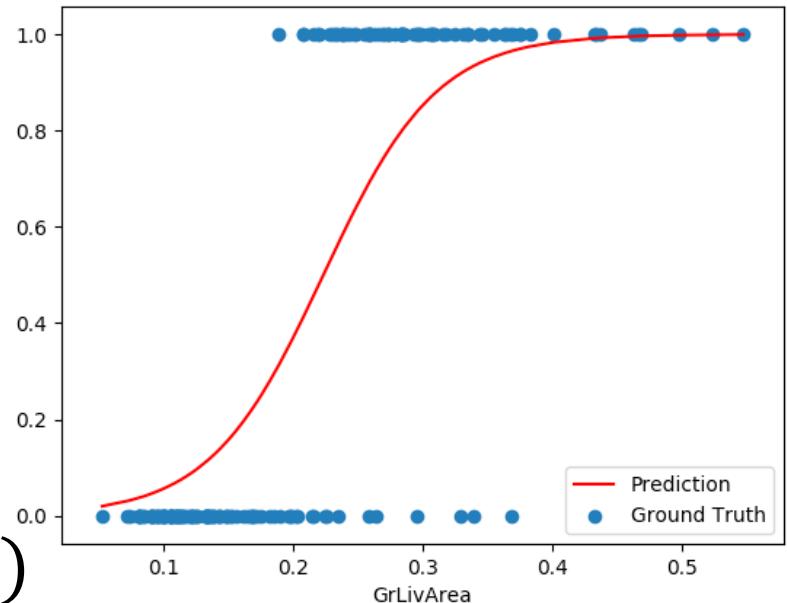
Submission 4 - Classifying House Prices

Logistic Regression:

$$y_i = \frac{1}{1 + \exp(-\theta_0 - \sum_{j=1}^d x_{ij}\theta_j)}$$

Cross Entropy Loss:

$$-\hat{y} \log(y) - (1 - \hat{y}) \log(1 - y)$$



Submission 4 - Classifying House Prices

1. Classifier:
Forward and
Backward Pass
2. BCE Loss:
Forward and
Backward Pass

3. Training with Solver
Test Accuracy > 85%

```
Evaluation of ex. 4. model file: logistic_regression.p. Submissions 1/5
```

```
ClassifierForward passed.
```

```
ClassifierBackward passed.
```

```
All tests of ClassifierEvaluation passed. Tests passed: 2/2
```

```
Score: 100/100
```

```
BCEForwardTest passed.
```

```
BCEBackwardTest passed.
```

```
All tests of BCETest passed. Tests passed: 2/2
```

```
Score: 100/100
```

```
Accuracy BEFORE training 41.8%
```

```
Training Parameters:
```

```
lr: 0.1
```

```
Epochs: 25000
```

```
(Epoch 0 / 25000) train loss: 0.692986; val_loss: 0.692684
```

```
(Epoch 500 / 25000) train loss: 0.628555; val_loss: 0.627406
```

```
(Epoch 1000 / 25000) train loss: 0.580014; val_loss: 0.580251
```

```
(Epoch 1500 / 25000) train loss: 0.542665; val_loss: 0.544227
```

```
(Epoch 24500 / 25000) train loss: 0.329405; val_loss: 0.345111
```

```
Accuracy AFTER training 91.5%
```

```
ClassifierPredictions passed.
```

```
Score: 100/100
```

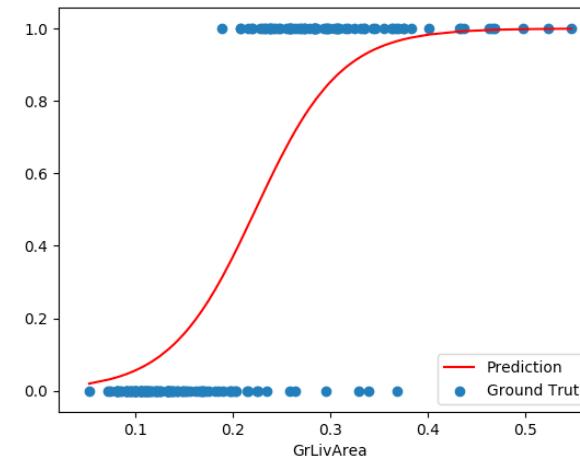
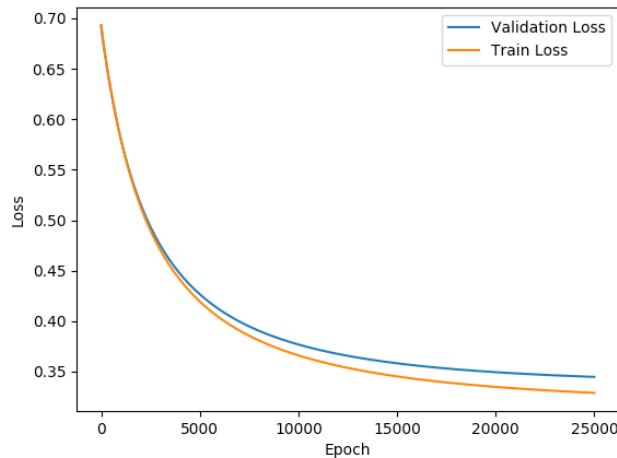
```
You can see a plot of your training performance here: http://filecremers3.informatik.tu-muenchen.de/~dl4cv/pub/ad761d6ea04ad79b01709e98f58808c6.png
```

```
You can see a plot of your prediction here: http://filecremers3.informatik.tu-muenchen.de/~dl4cv/pub/3593449865fd051721be8e2ae731ec7.png
```

```
This model reached the required score in order to be eligible for the bonus points!
```

```
The achieved score for this model is: 100.00
```

Submission 4 - Classifying House Prices



```
(Epoch 24500 / 25000) train loss: 0.329405; val_loss: 0.345111  
Accuracy AFTER training 91.5%
```

```
ClassifierPredictions passed.  
Score: 100/100
```

```
You can see a plot of your training performance here: http://filecremers3.informatik.tu-muenchen.de/~dl4cv/pub/ad761d6ea04ad79b01709e98f58808c6.png  
You can see a plot of your prediction here: http://filecremers3.informatik.tu-muenchen.de/~dl4cv/pub/3593449865f7d051721be8e2ae731ec7.png  
This model reached the required score in order to be eligible for the bonus points!  
The achieved score for this model is: 100.00
```

Submission 4: Logistic Regression

Start: May 14, 2020 12.00

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See you next week

