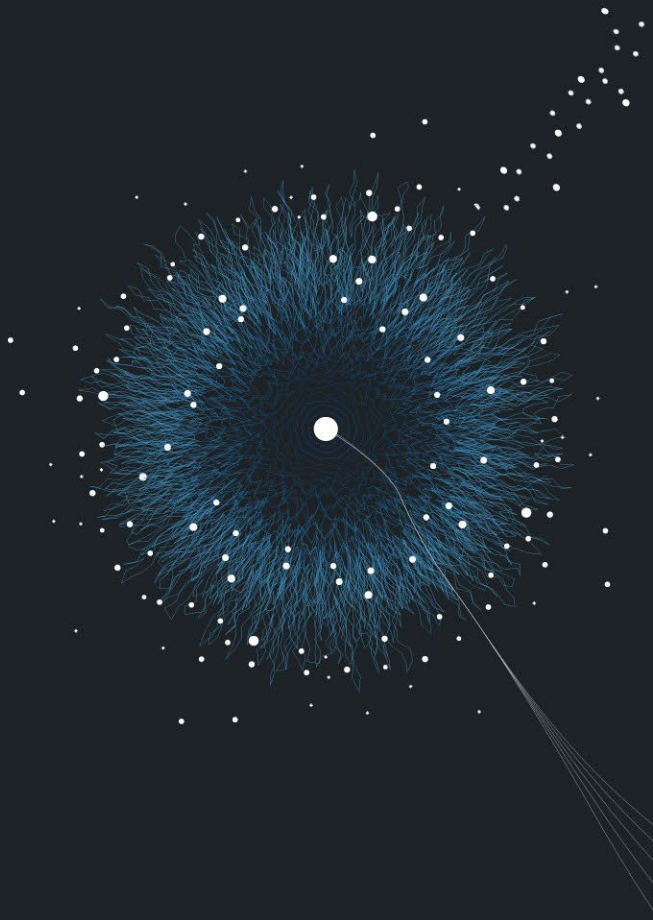
De wiskunde achter medische machine learning

Dieuwertje Alblas, Clara Stegehuis

WELKOM BIJ
APPLIED MATHEMATICS @ UT

Workshop medical machine learning



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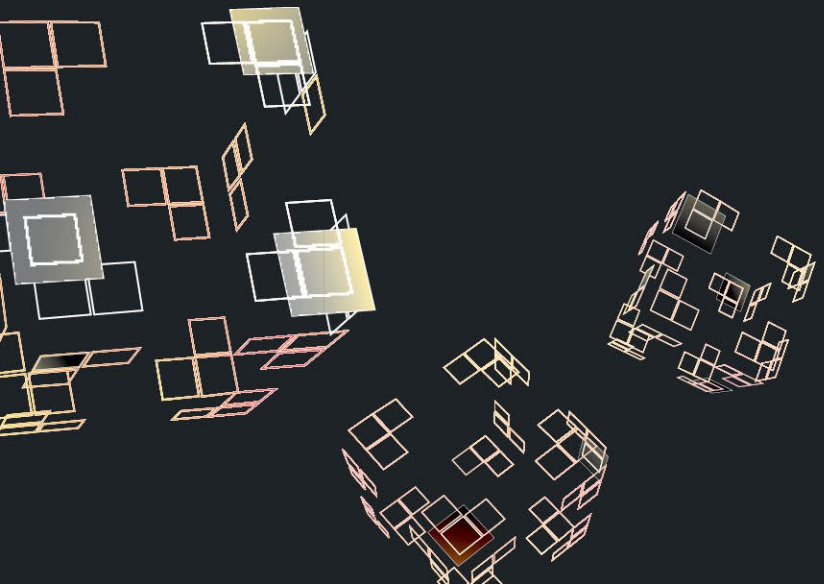
PROGRAMMA

13:00-13:10 |	Welkom
13.10 - 14.10 |	Beeldalyse: Theorie
14.10 - 14.30 |	Pauze
14:30 –16:00 |	programmeren
16:00 - 16:30 |	Presentatie medical machine learning Dieuwertje



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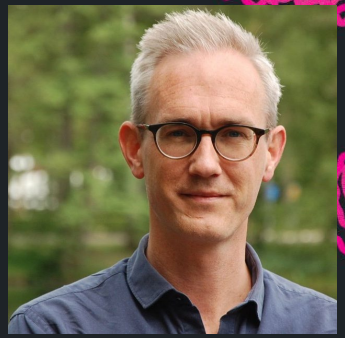
Wie zijn wij?

Clara Stegehuis

Dieuwertje Alblas



Pim van t Hof

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APPLIED MATHEMATICS IS ENERGY EFFICIENCY

APPLIED MATHEMATICS IS ENGINEERING

Voorbeeld van een vak

Deep Learning for 3D Medical Image Analysis

- Convolutional neural networks
- Explainability in deep learning models
- Wiskundige beeldanalyse
- Interdisciplinair: wiskunde, informatica, biomedische technologie & technisch geneeskunde

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De wiskunde achter medische machine learning

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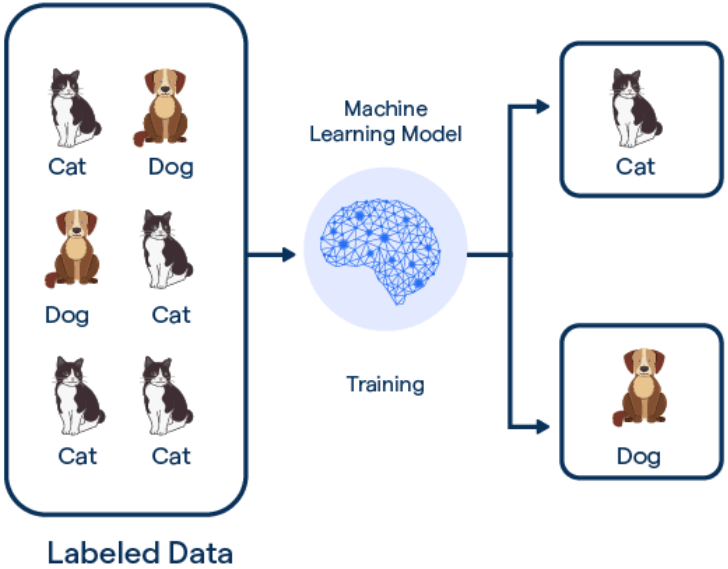
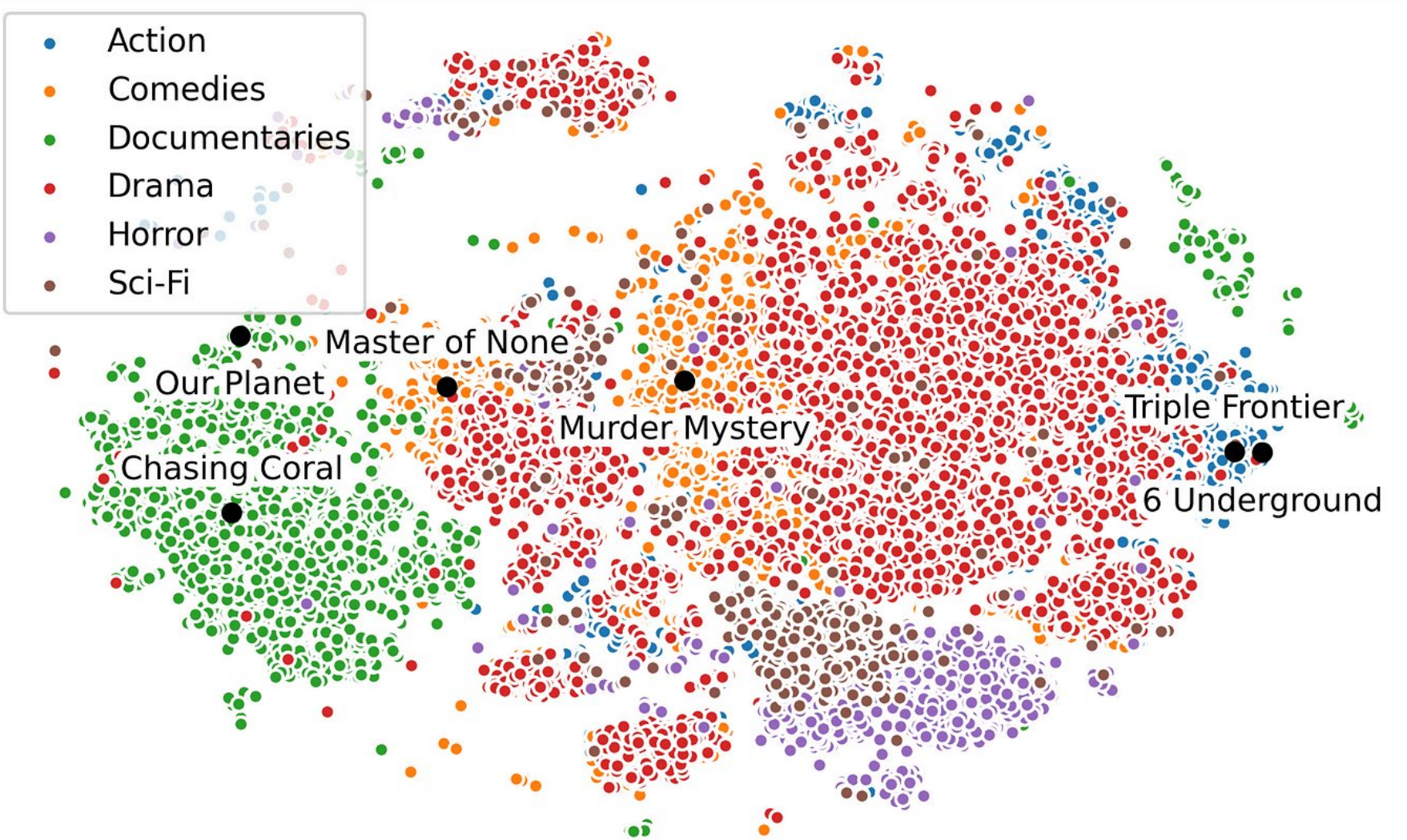
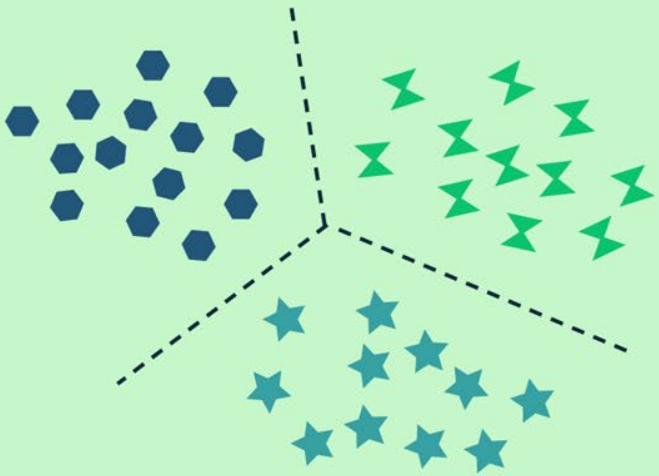
Supervised/ unsupervised learning

Supervised learning



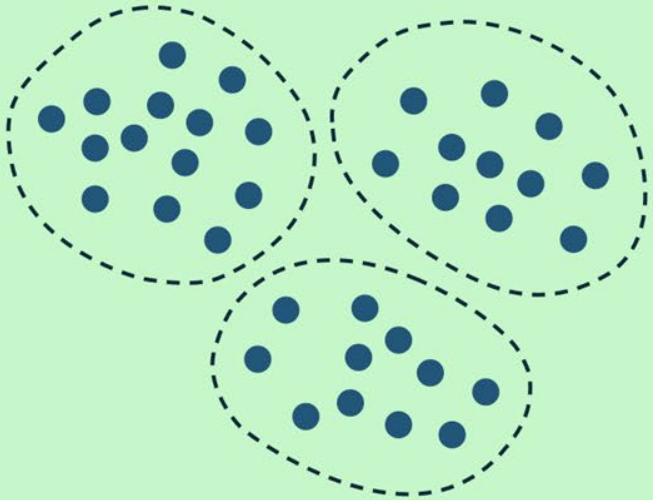

Action
Comedies
Documentaries
Drama
Horror
Sci-Fi
Master of None
Our Planet
Murder Mystery
Triple Frontier
Chasing Coral
6 Underground

Classification



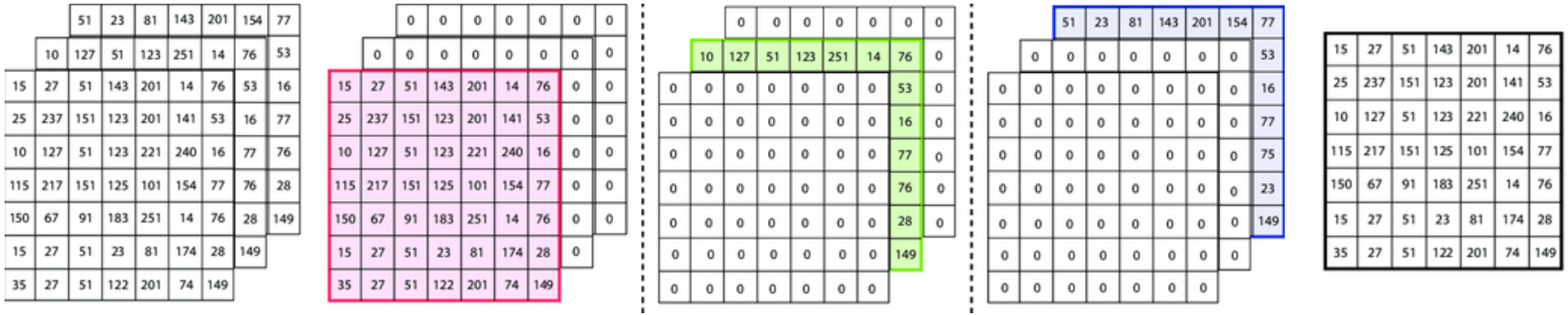
Supervised learning

Clustering



Unsupervised learning

Hoe ziet de computer een beeld?



Convolutie

- Beeld I:

$$I = \begin{bmatrix} I_{11} & \cdots & I_{1n} \\ \vdots & \ddots & \vdots \\ I_{n1} & \cdots & I_{nn} \end{bmatrix}$$

- Kernel: een kleine matrix

$$K = \begin{bmatrix} w_{11} & \cdots & w_{1k} \\ \vdots & \ddots & \vdots \\ w_{k1} & \cdots & w_{kk} \end{bmatrix}$$

- Feature map

$$f(i,j) = \sum_{x=1}^{k} \sum_{y=1}^{k} K_{x,y} * I_{i+x-1,j+y-1}$$

Convolutie

Input Image

252	251	246	207	90
250	242	236	144	41
252	244	228	102	43
250	243	214	59	52
248	243	201	44	54

Feature map

Kernel

1	0	-1
1	0	-1
1	0	-1

Receptive field

X

=

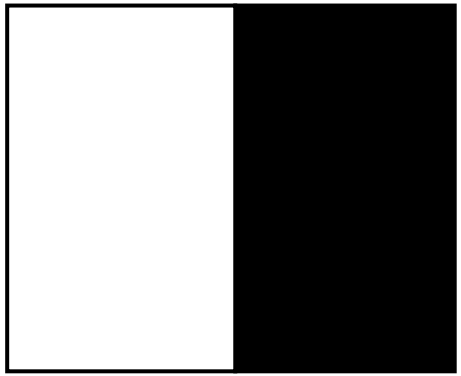
Grootte output

Als je beeld $n \times n$ is en je kernel $k \times k$ pixels, hoe groot is dan de output na convolutie?

a) $n \times n$
b) $k \times k$
c) $n - k \times n - k$

Voorbeeld

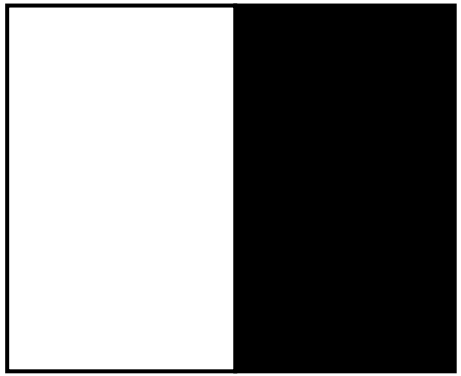
$$K = \begin{bmatrix} 1 & 0 & -1 \\ 1 & 0 & -1 \\ 1 & 0 & -1 \end{bmatrix}, I =$$



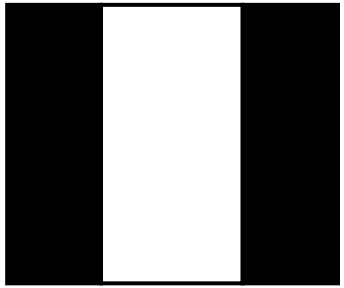
Wat is de uitkomst van de convolutie van K en I?

Voorbeeld

$$K = \begin{bmatrix} 1 & 0 & -1 \\ 1 & 0 & -1 \\ 1 & 0 & -1 \end{bmatrix}, I =$$

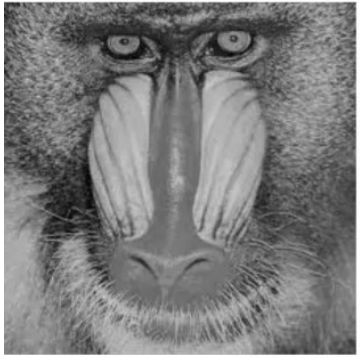


$$F =$$



Vraag

Wat doet deze kernel?



Convolutie zoekt naar patroon in kernel

Afbeelding 1

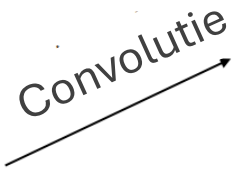
0	0	0
0	1	0
0	1	1

Afbeelding 2

1	0	1
0	1	0
0	0	0

Kernel

0	0	0
0	1	0
0	1	1



0	0	0
0	1	0
0	1	1

$= 3$

0	0	0
0	1	0
0	0	0

$= 1$

Input

Kernel

Result

Input

Kernel

Result

Input

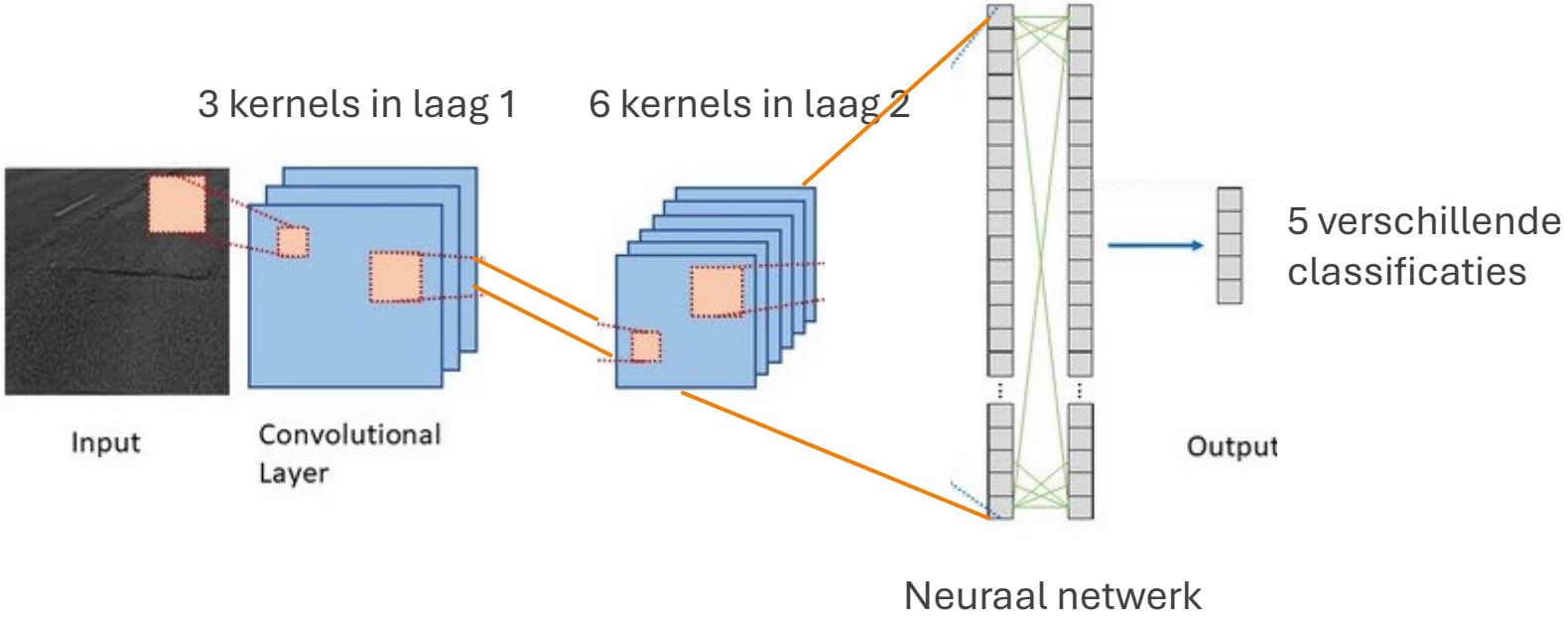
Kernel

Result

Neuraal netwerk

- Leert de ‘beste’ gewichten w_{ii} van de kernels op de trainingsdata

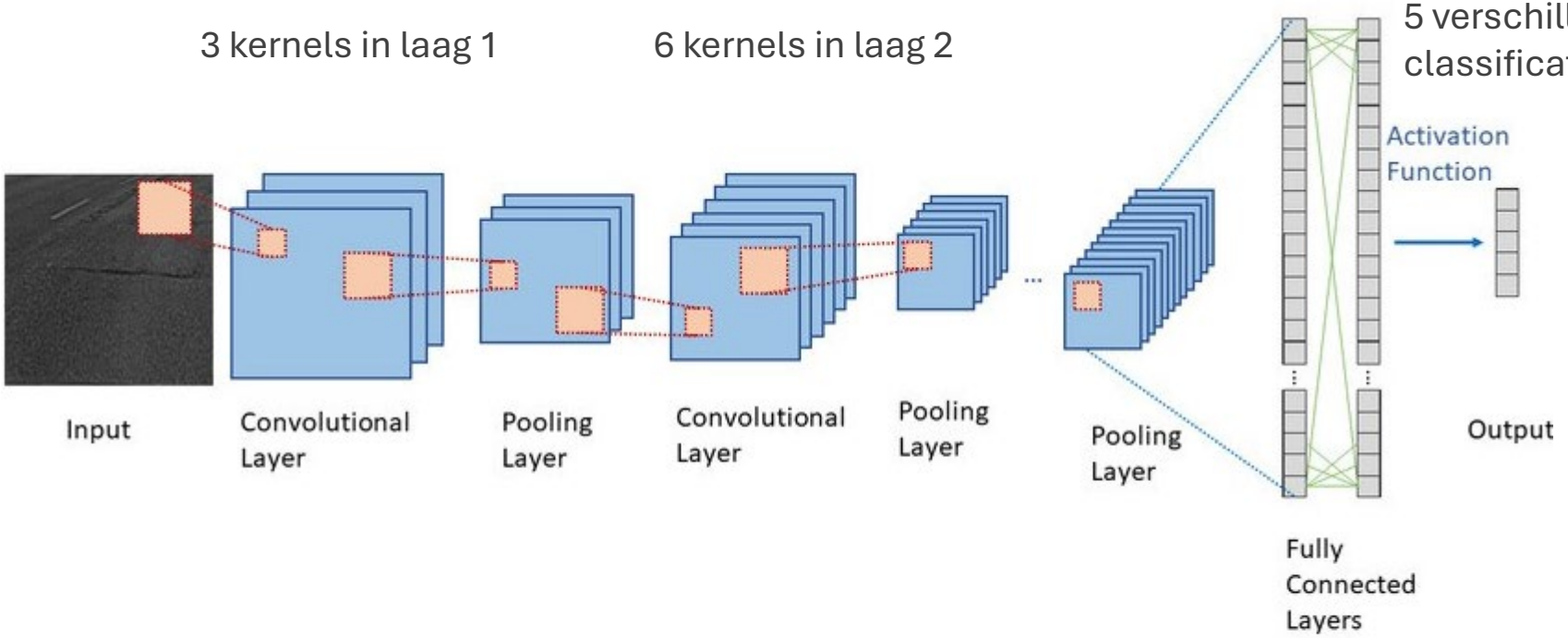
$$K = \begin{bmatrix} w_{11} & \cdots & w_{1k} \\ \vdots & \ddots & \vdots \\ w_{k1} & \cdots & w_{kk} \end{bmatrix}$$


3 kernels in laag 1
6 kernels in laag 2
Input
Convolutional Layer
Output
5 verschillende classificaties
Neuraal netwerk

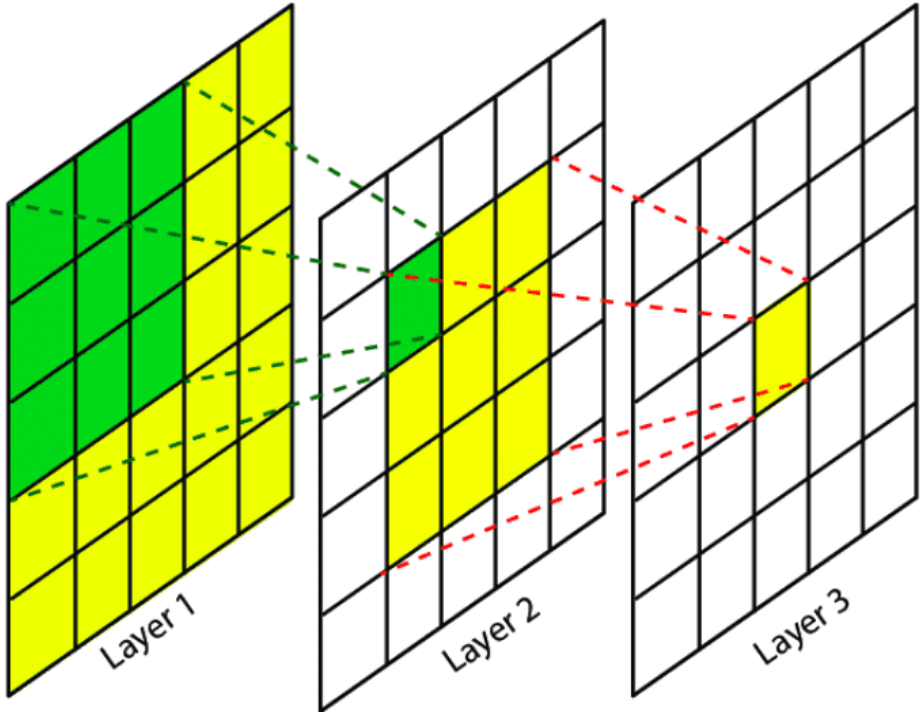
3 kernels in laag 1

6 kernels in laag 2

5 verschillende classificaties

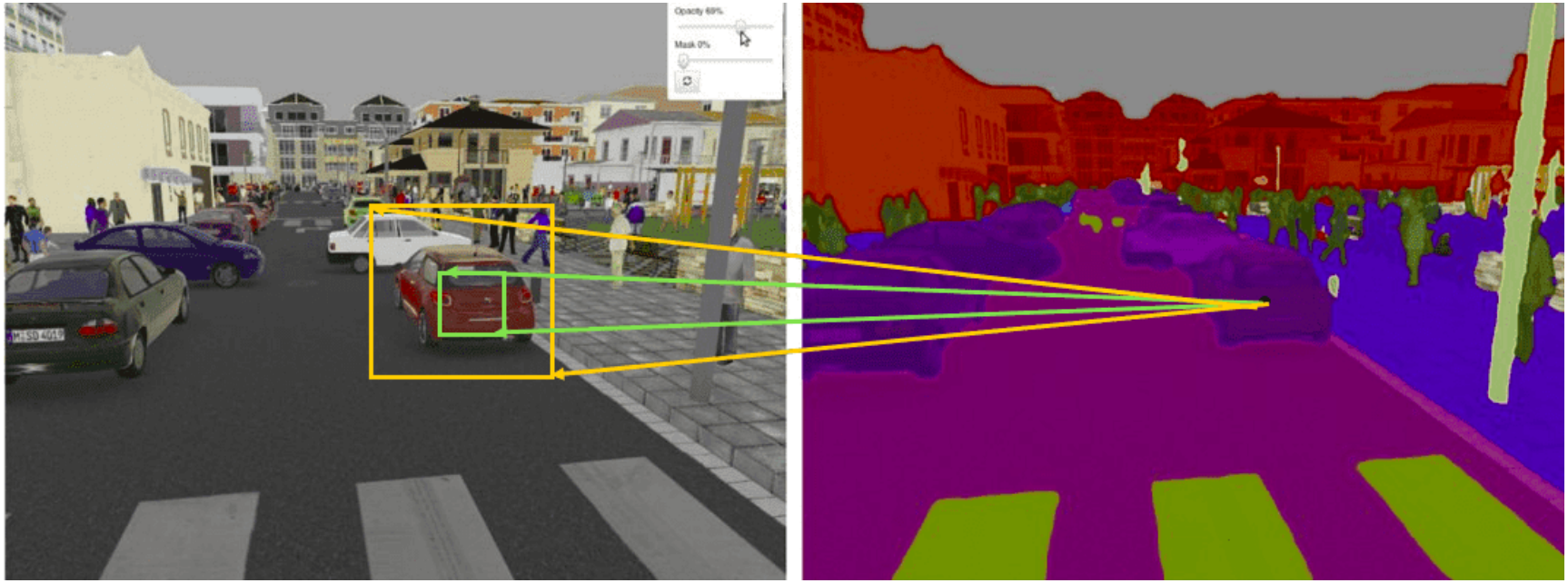


Receptive field



$$R = 1 + \sum_{i=1}^{L} (k_i - 1)$$

$$R = 1 + (3 - 1) + (3 - 1) = 5$$


Opacity 69%
Mask 0%

Welke kernel

Algoritme leert welke kernels het beste classificeren

Binaire output

$x_i = 0$

Echte labels: $x_i \in \{0,1\}$
Output: $y_i \in [0,1]$

$x_i = 1$

Binaire output

Echte labels: $x_i \in \{0,1\}$
Output: $y_i \in [0,1]$

$y_i = 0.9$

$y_i = 0.1$

$y_i = 0.45$

Loss functie

$$H(N) = -\frac{1}{N}\sum(x_i \log(y_i) + (1 - x_i)\log(1 - y_i))$$

Echte labels: $x_i \in \{0,1\}$
Output: $y_i \in [0,1]$

Loss functie

$$H(N) = \quad -x_i \log(y_i) - (1 - x_i)\log(1 - y_i)$$

Echte labels: $x_i \in \{0,1\}$
Output: $y_i \in [0,1]$

Loss functie

$$H(N) = \quad -x_i \log(y_i) - (1 - x_i)\log(1 - y_i)$$

Vraag: Als x_i en y_i op elkaar lijken dan:

A) Is de loss functie groot
B) Is de loss functie klein

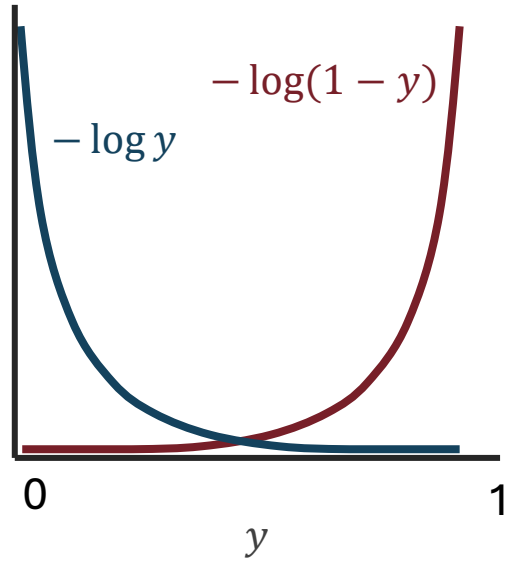
Loss functie

$$H(N) = -x_i \log(y_i) - (1 - x_i)\log(1 - y_i)$$

Echte labels: $x_i \in \{0,1\}$
Output: $y_i \in [0,1]$

Als $x_i = 1$: $-\log(y_i)$

Als $x_i = 0$: $-\log(1 - y_i)$

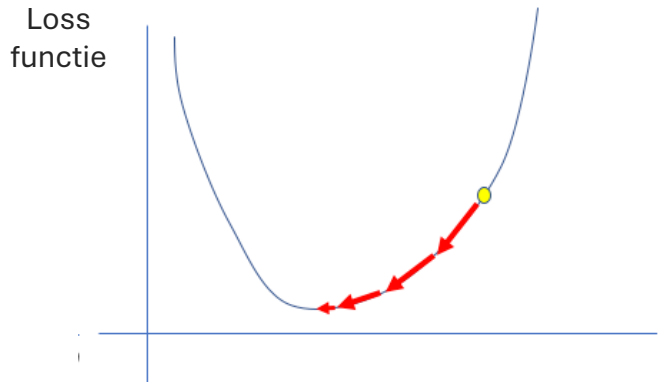


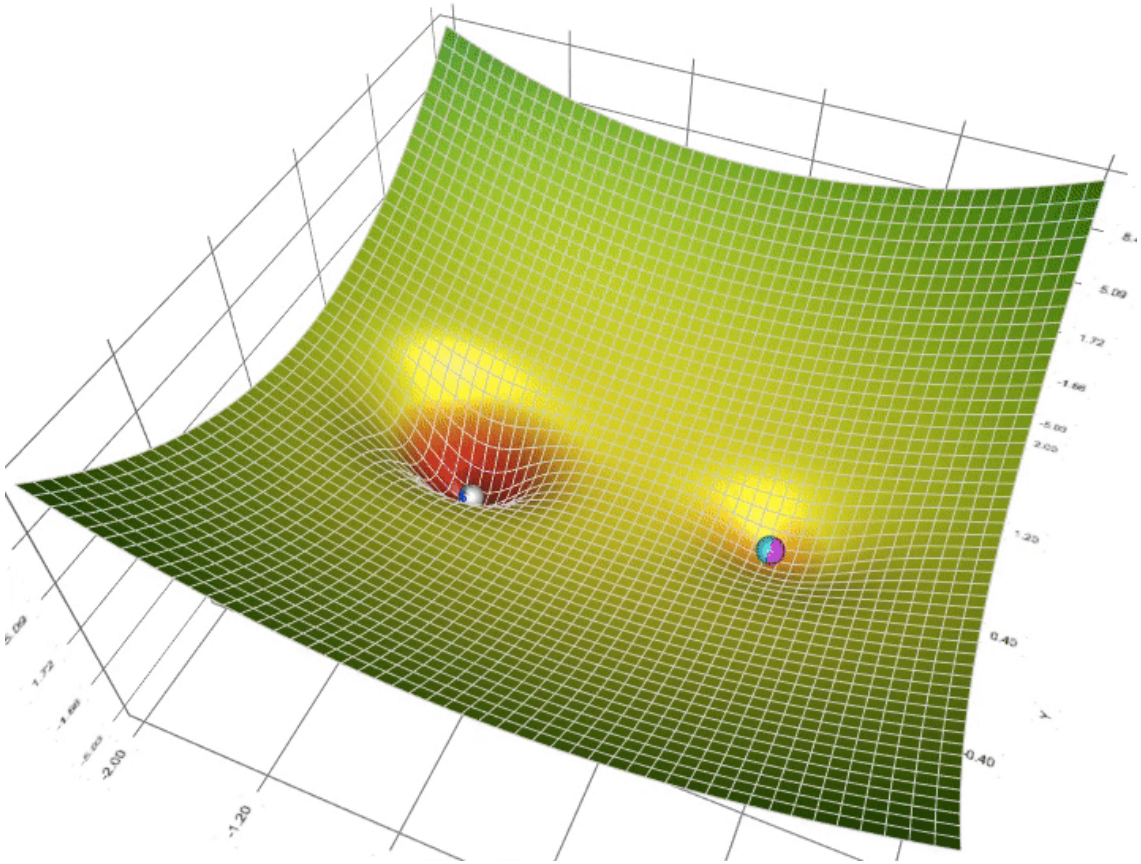
Hoe minimaliseer je de loss functie?

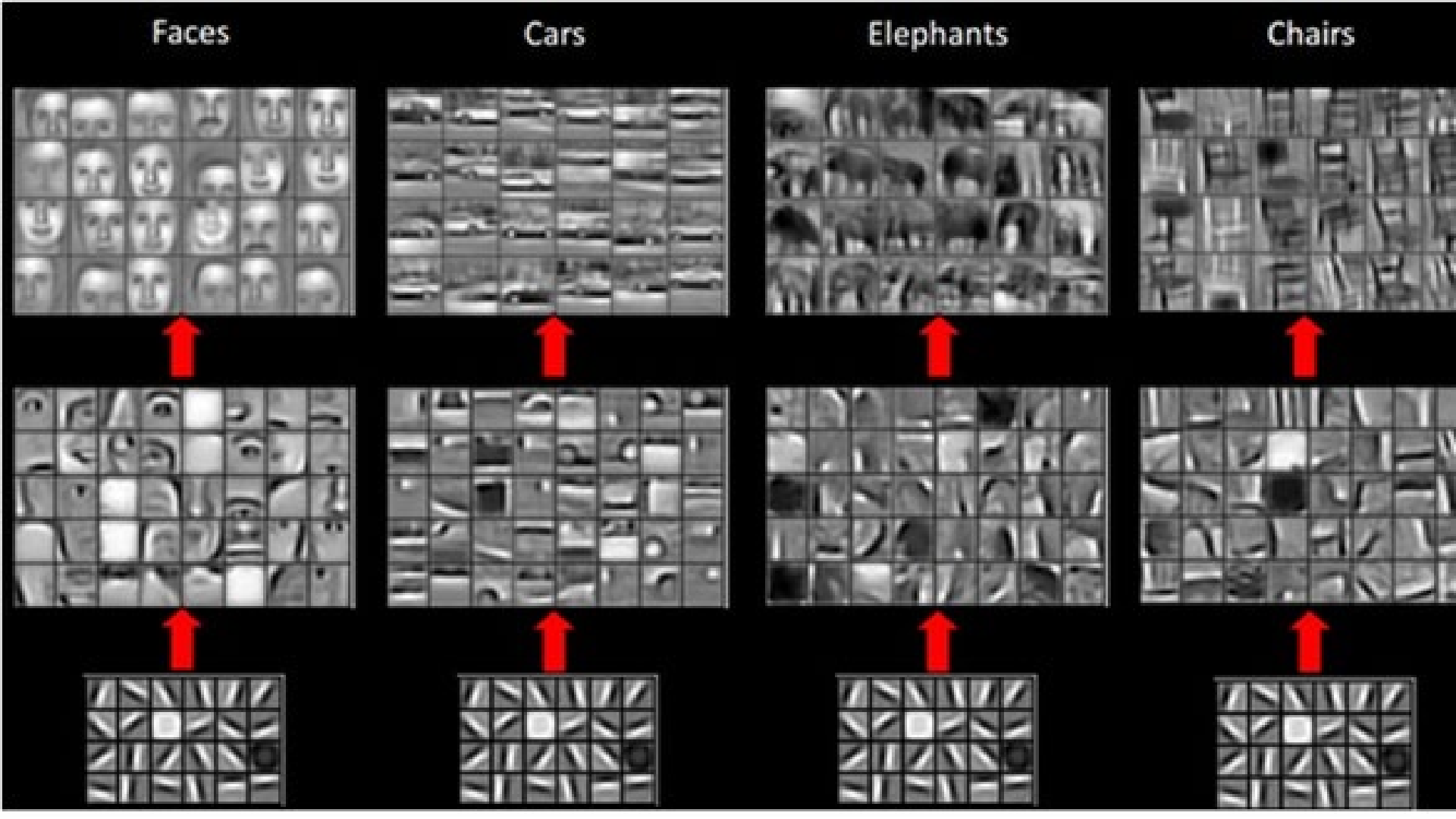
- Begin met willekeurige kernels
- In iedere tijdsstap, bereken

$$\frac{\partial L}{\partial W_i}$$

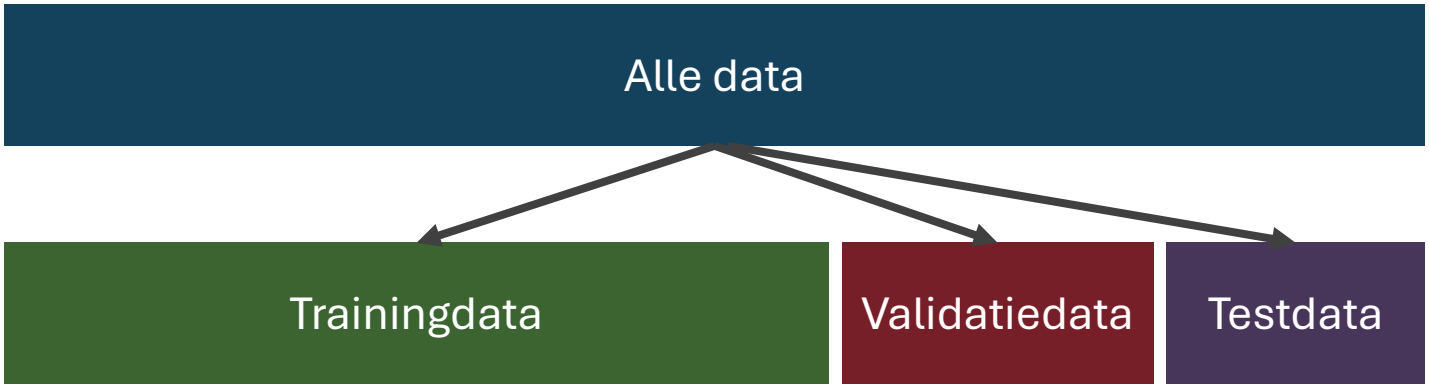
- $W_i = W_i - \alpha \frac{\partial L}{\partial W_i}$




-2.00
-1.20
0.40
-0.40


Faces
Cars
Elephants
Chairs

Overfitting



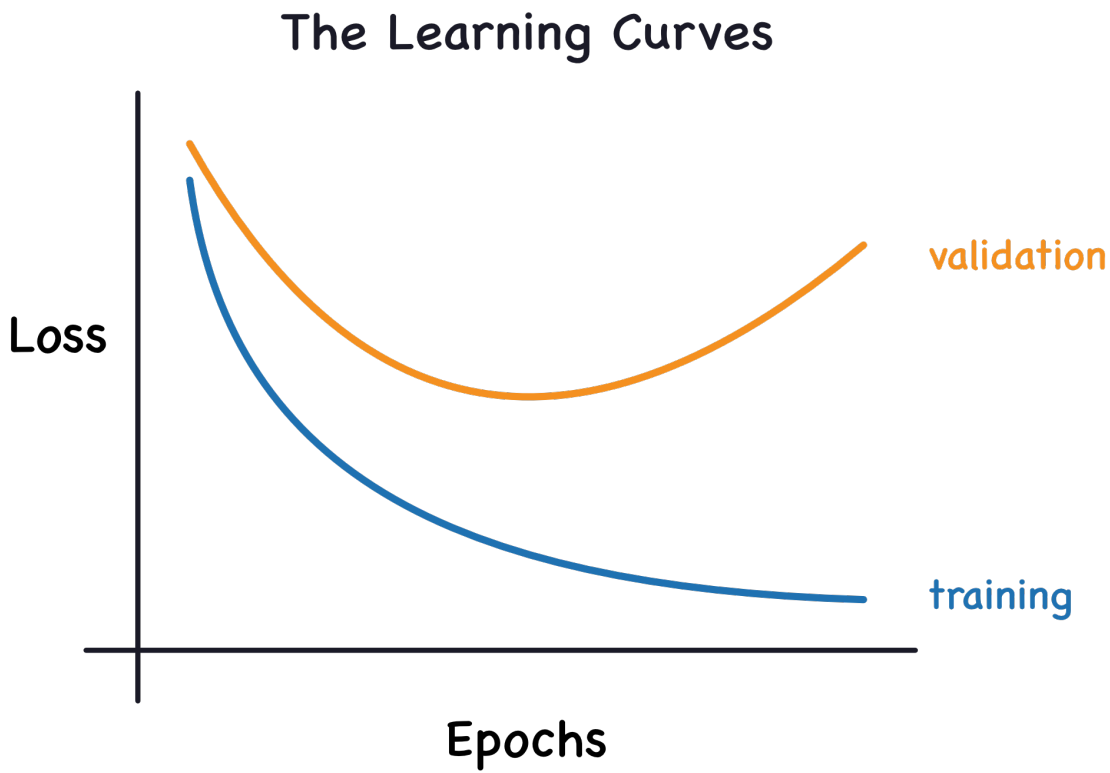
Train de gewichten van de kernels

Selecteer het beste model

Test hoe goed het model werkt

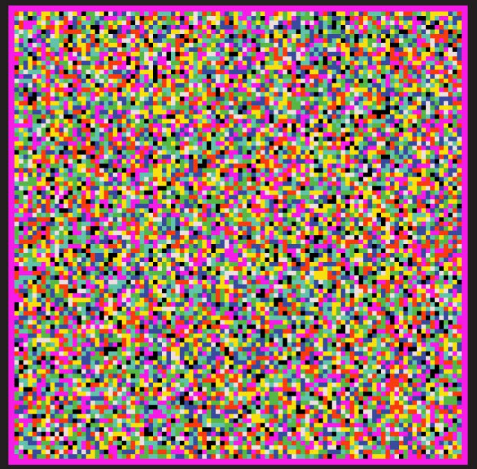
Overfitting

Groeiend ‘gat’ tussen performance op de validatie- en trainingsdata tijdens training.



PANDA

+

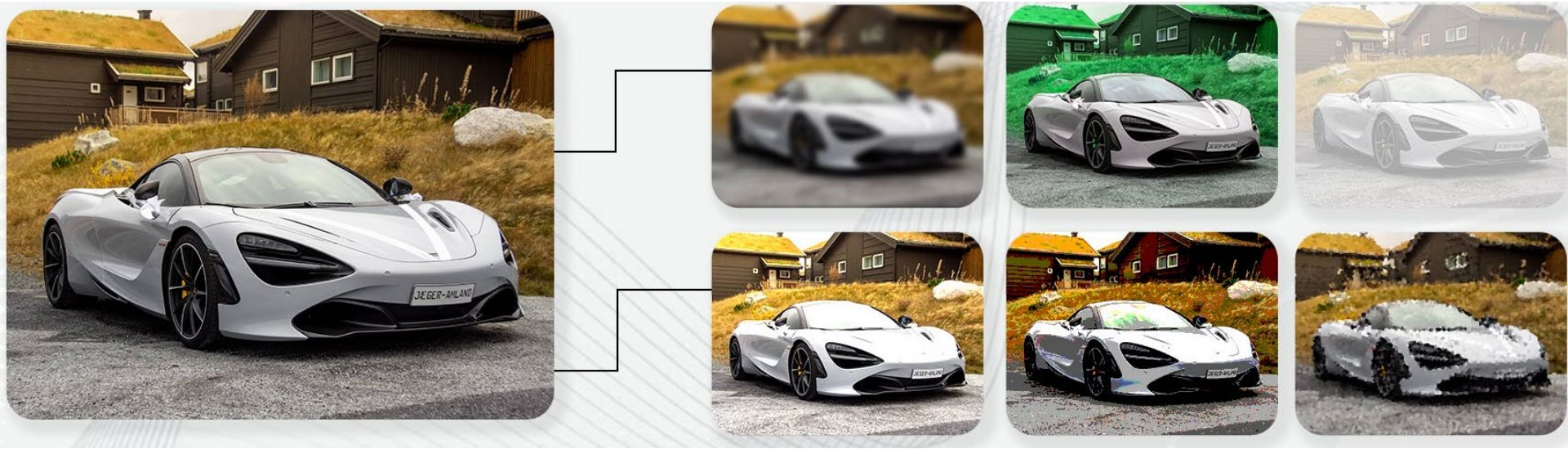


NOISE

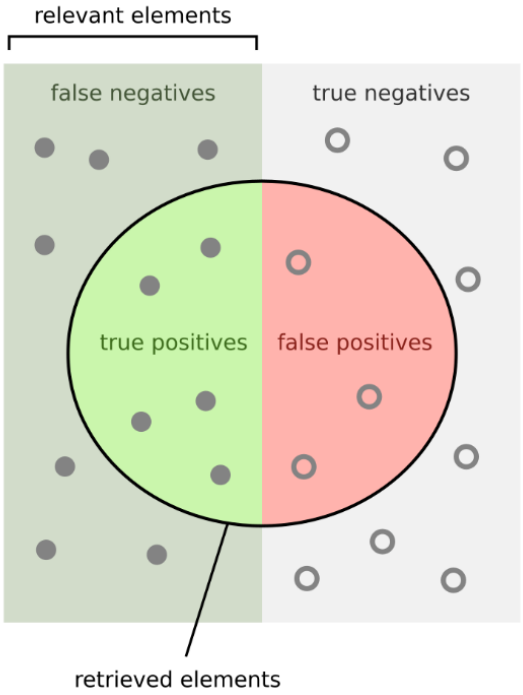
=

GIBBON

Overfitting voorkomen: Data augmentatie



Wanneer werkt een algoritme goed?



How many retrieved items are relevant?

Precision = $\frac{\text{true positives}}{\text{retrieved elements}}$

How many relevant items are retrieved?

Recall = $\frac{\text{true positives}}{\text{relevant elements}}$

Zeldzame ziekte

Stel dat een ziekte bij 1% van de bevolking voorkomt.
Een classificatiealgoritme heeft een accuracy van 99%. Is dit een goed algoritme?

Longontsteking of niet?

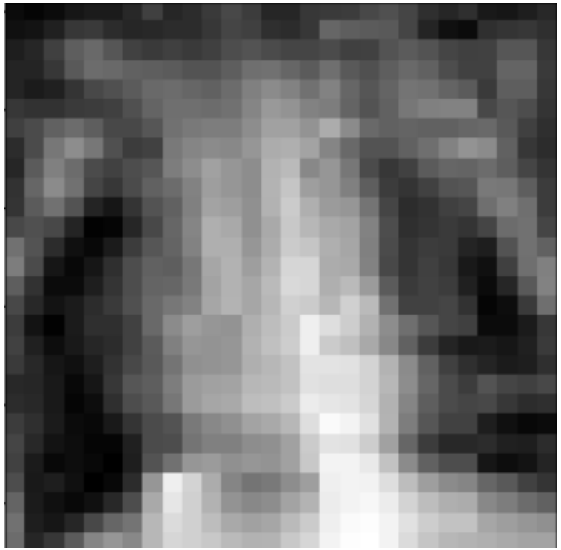
(a) Normal

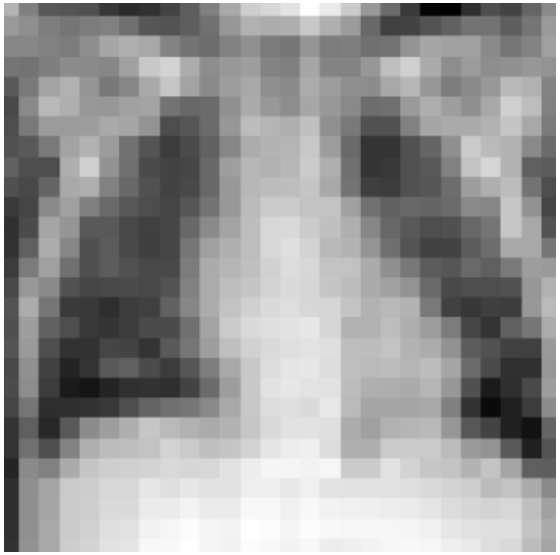
(b) Bacterial Pneumonia

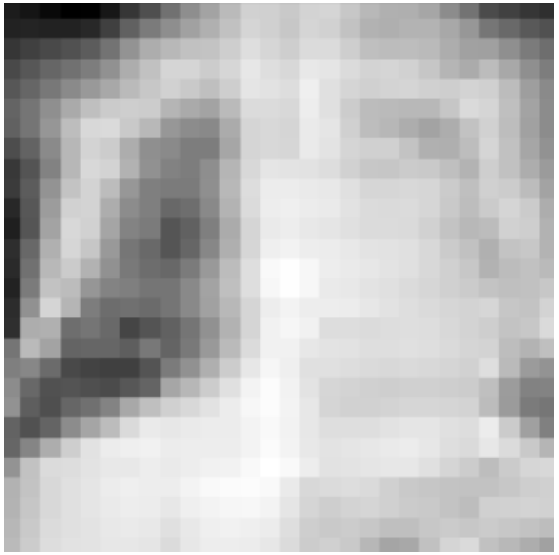
(c) Viral Pneumonia

(d) COVID-19 Pneumonia

Ben jij beter dan AI?







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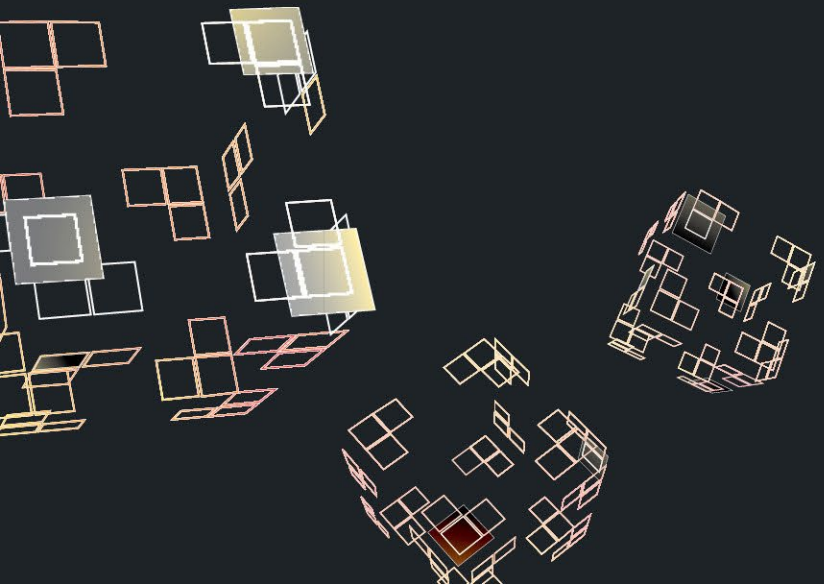

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En nu aan de slag!

Ga naar
https://colab.research.google.com/github/clarastegehuis/machine_learning_medical_data_workshop/

Selecteer in ‘Runtime’ onder ‘select runtime’ GPU

Feedback