Residual Networks & Densly Connected Convolutional Networks

Alexander Bierenstiel

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Hochschule Offenburg
University of Applied Sciences

Outline

ResNet (published 2015)

- Architecture
- Properties

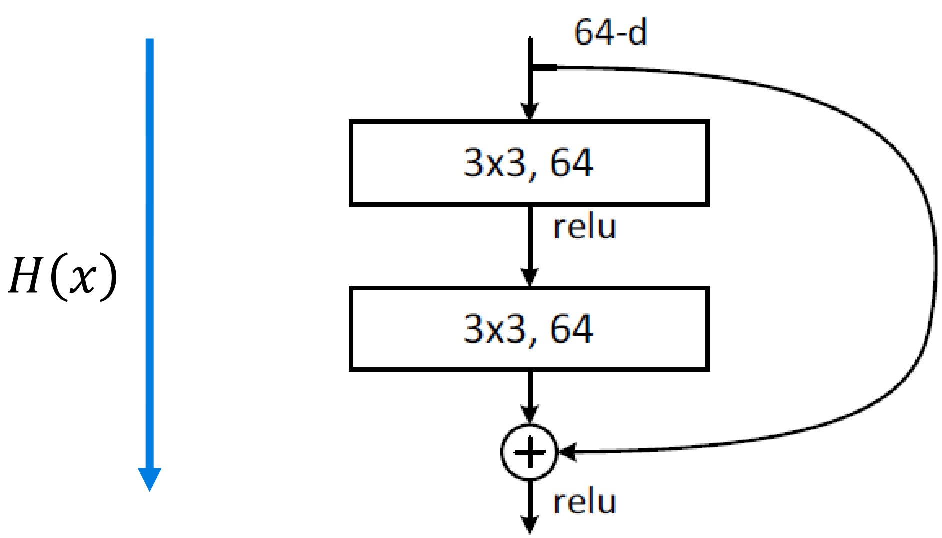
DenseNet (published 2018)

- Architecture
- Properties

Experiments

ResNet
Residual Unit

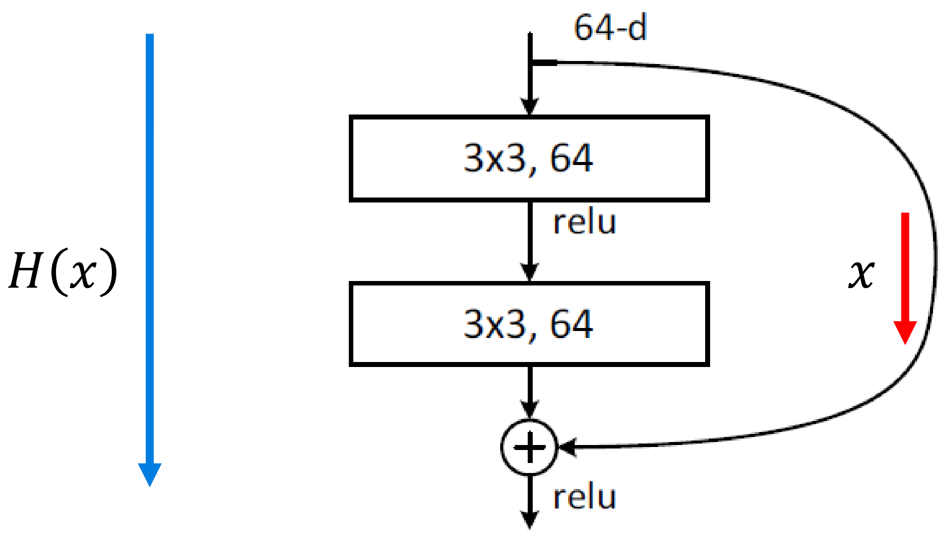
- $H(x)$ old mapping



Source: (modified) Paper „Deep Residual Learning for Image Recognition"

ResNet
Residual Unit

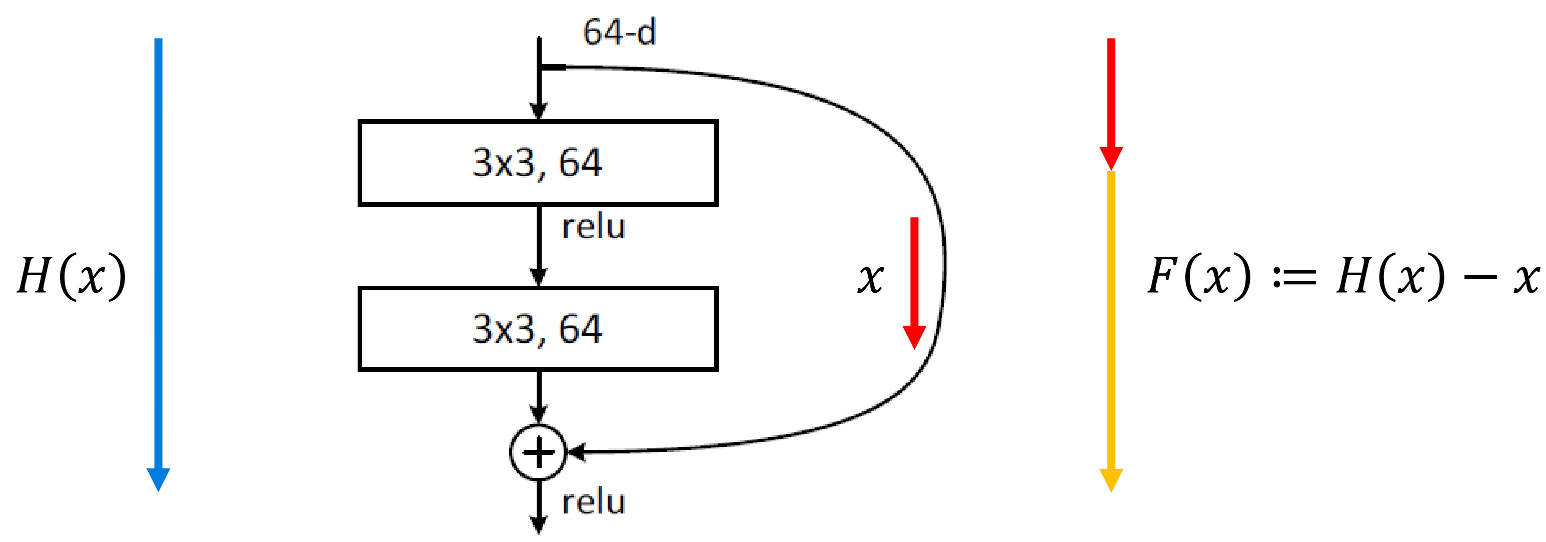
- $H(x)$ old mapping
- x skip connection / identity



Source: (modified) Paper „Deep Residual Learning for Image Recognition”

ResNet
Residual Unit

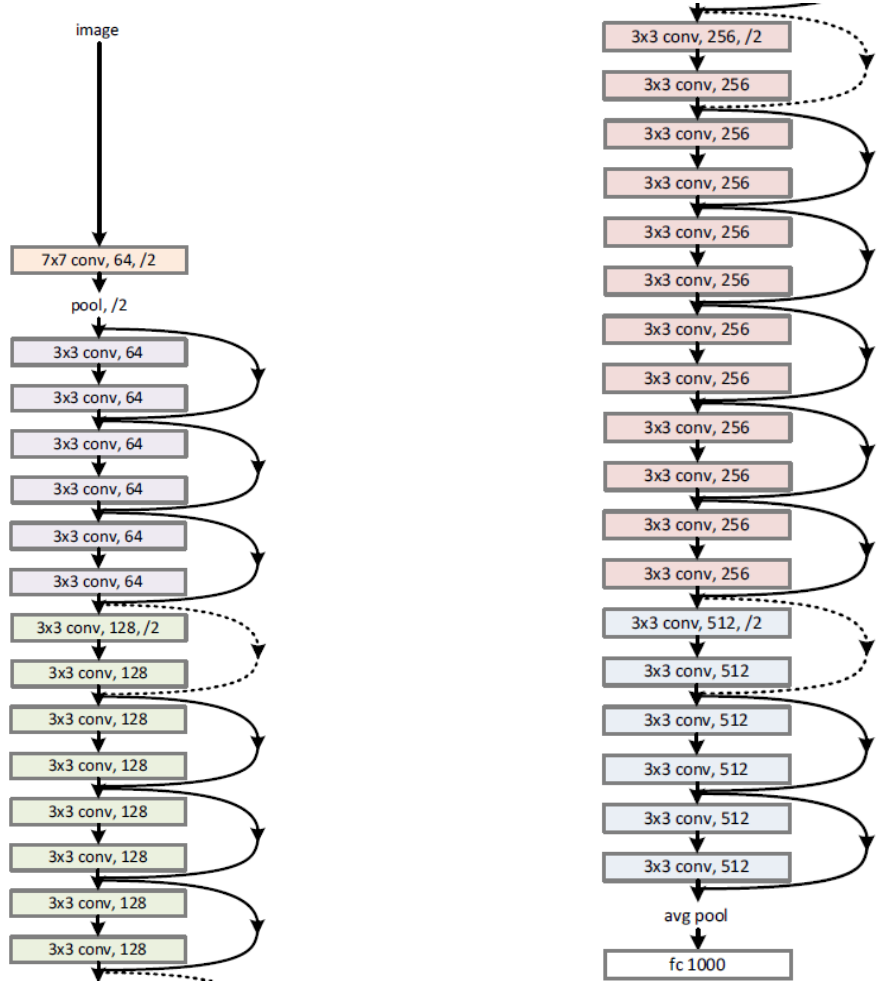
- $H(x)$ old mapping
- x skip connection / identity
- $F(x)$ new mapping with skip connection



Source: (modified) Paper „Deep Residual Learning for Image Recognition"

ResNet
Architecture

34-layer residual

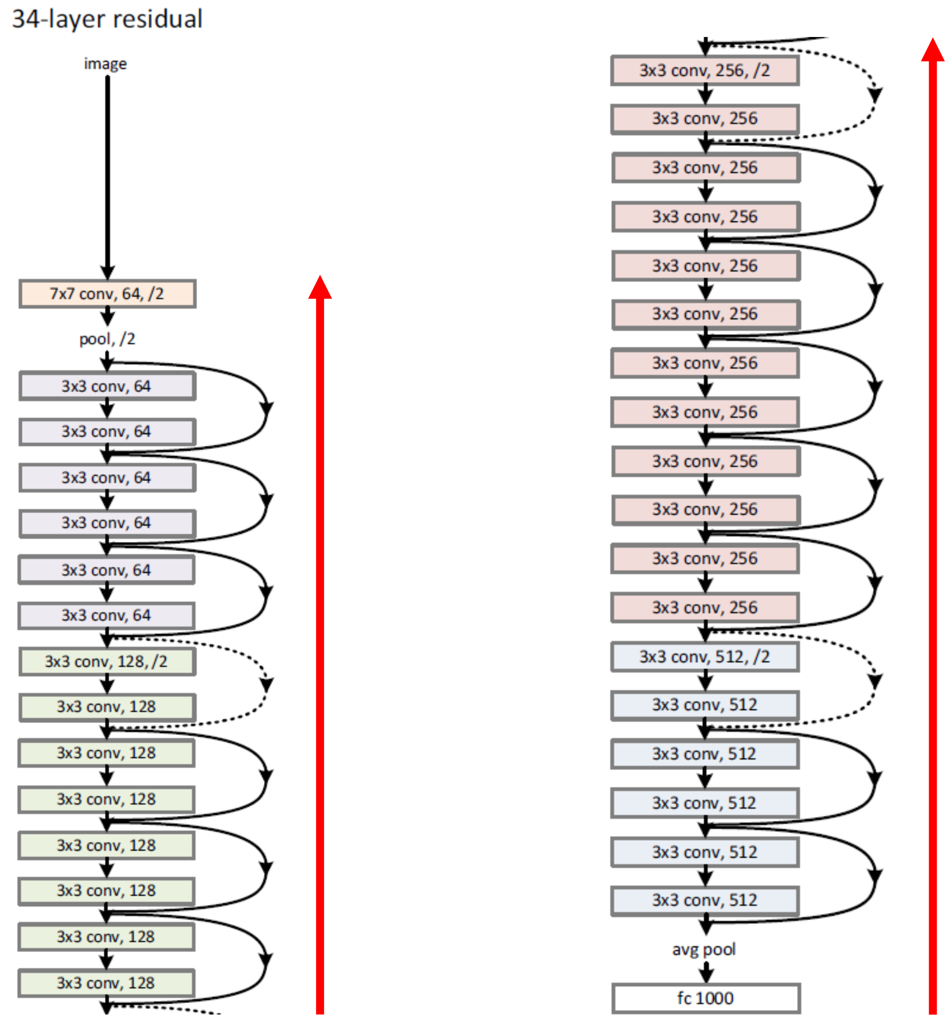


Source: „Deep Residual Learning for Image Recognition”

ResNet
Gradient Flow

Improved gradient flow

through skip connections

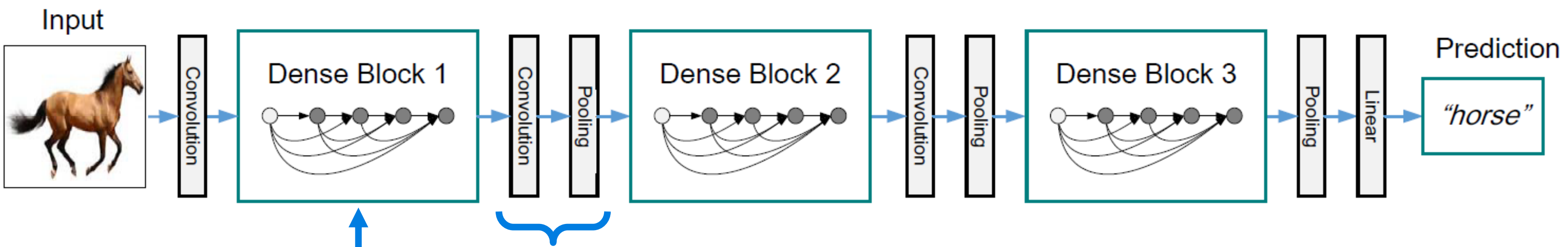


Source: (modified) Paper „Deep Residual Learning for Image Recognition"

ResNet
Properties

- **Improved gradient flow**
  - Less prone to vanishing gradients
  - Deeper networks are trainable
- **Feauture propagation through skip connections**
- **Skip connections are computationally cheap**

DenseNet
Architecture



Transition layer:
Reduce number of feature maps,
Reduce width and height of feature maps

Create new feature maps and concatenate them

Source: Paper „Densely Connected Convolutional Networks“

DenseNet
Architecture II

- $H(\cdot)$ Composite function (Batch Norm., ReLU, Conv., Pooling)
  e.g. Transition layer:

$$H(x_l) = Conv\big(Pooling(x_l)\big)$$

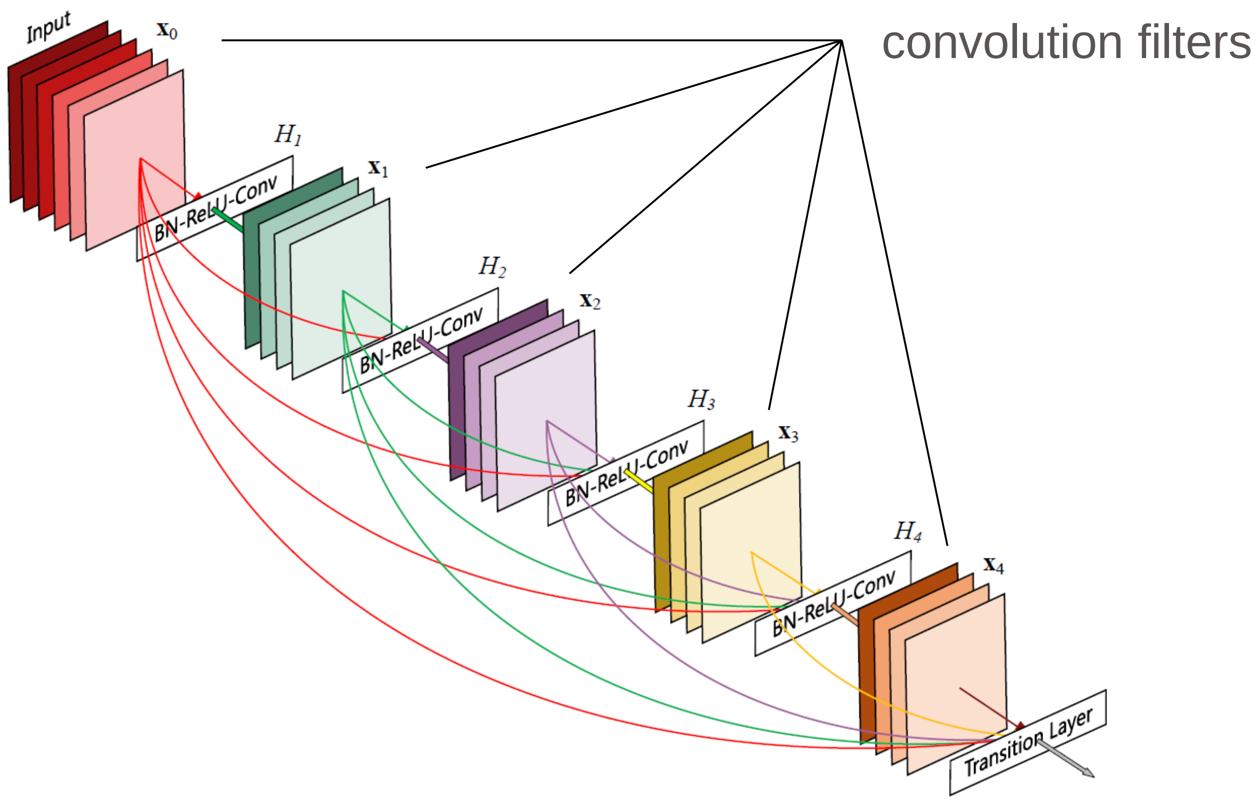
- ResNet:

$$x_l = H_l(x_{l-1}) + x_{l-1}$$

- DenseNet:

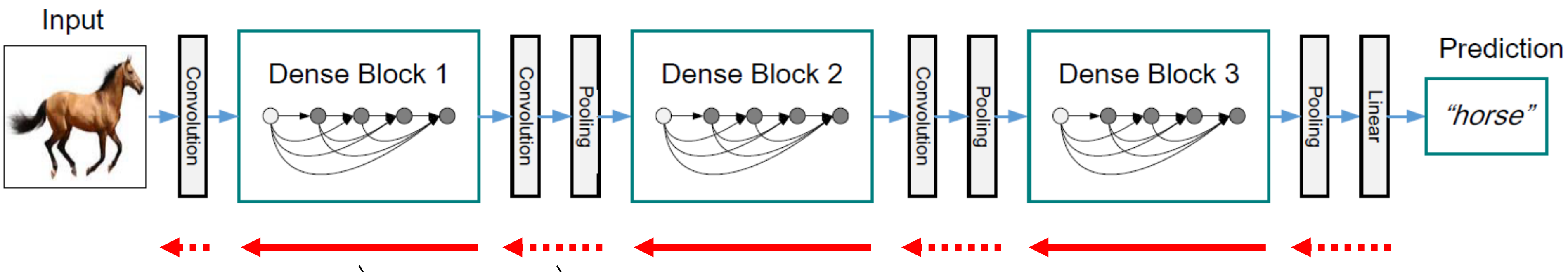
$$x_l = H_l([x_0, x_1, \dots, x_{l-1}])$$

DenseNet
Dense Block Architecture



Source: Paper „Densely Connected Convolutional Networks“

DenseNet
Gradient Flow



ordinary gradient flow

improved gradient flow
through many skip connections

Source: Paper „Densely Connected Convolutional Networks“

DenseNet
Properties

Similarities compared to ResNet:

- Uses skip connections
- Less prone to vanishing gradients

Differences compared to ResNet:

- Deeper networks are trainable
- Less parameters to learn
  - Less filters per convolution layer
- Combine feature maps by concatenation
  - Enables feature reuse
- Better accuracy

Experiments

Dataset

- Data from HS Offenburg Sweaty team
- Small dataset excerpt:
  - 8 Classes
  - 4917 Training images
  - 1230 Test images

Source: https://sweaty.hs-offenburg.de/projekt/

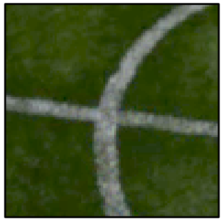
Dataset

Ball

Goal post

Obstacle

L-Line



X-Line

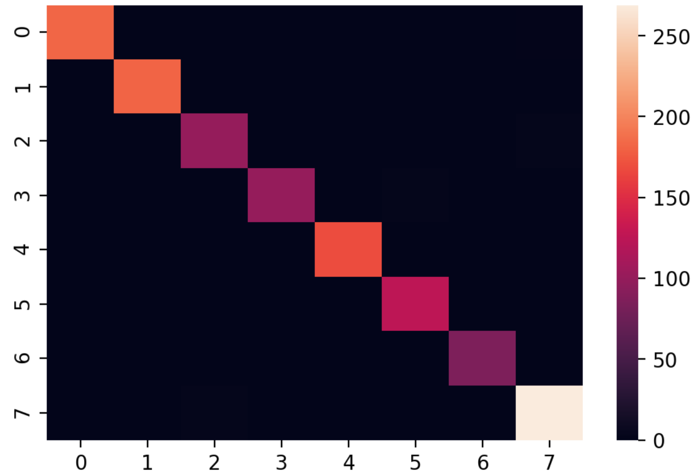
T-Line

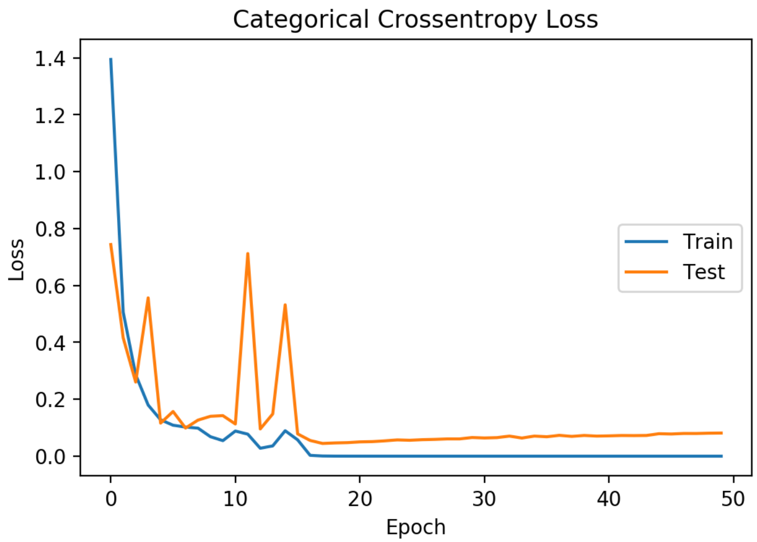
Penalty spot

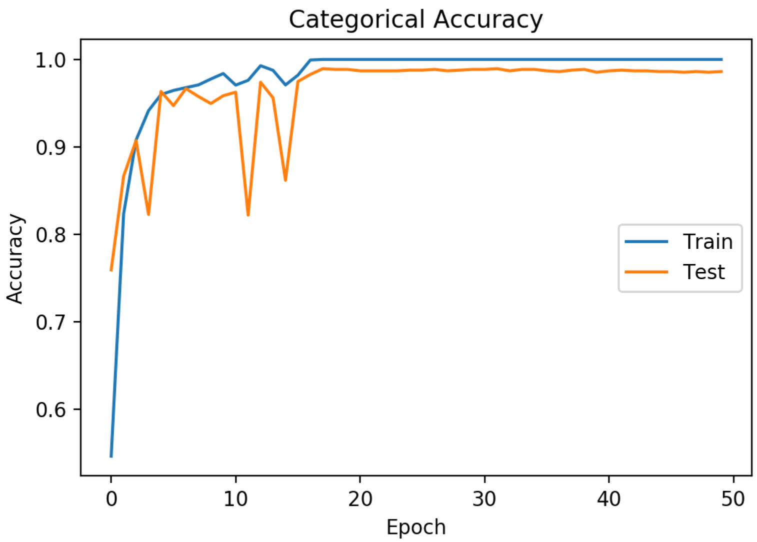
Robot foot

ResNet-50 Performance
Overview

2,5 h	Training time
1230	Test images
17	False predictions
1,38%	Error rate





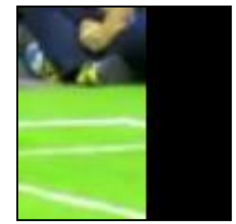


ResNet-50 Performance
False Predictions

Robot foot
(Ball)

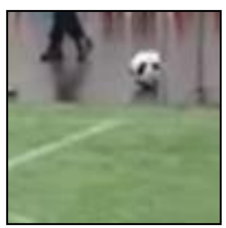
Goal post

Goal post
(Obstacle)



T-Line
(L-Line)

Robot foot
(X-Line)

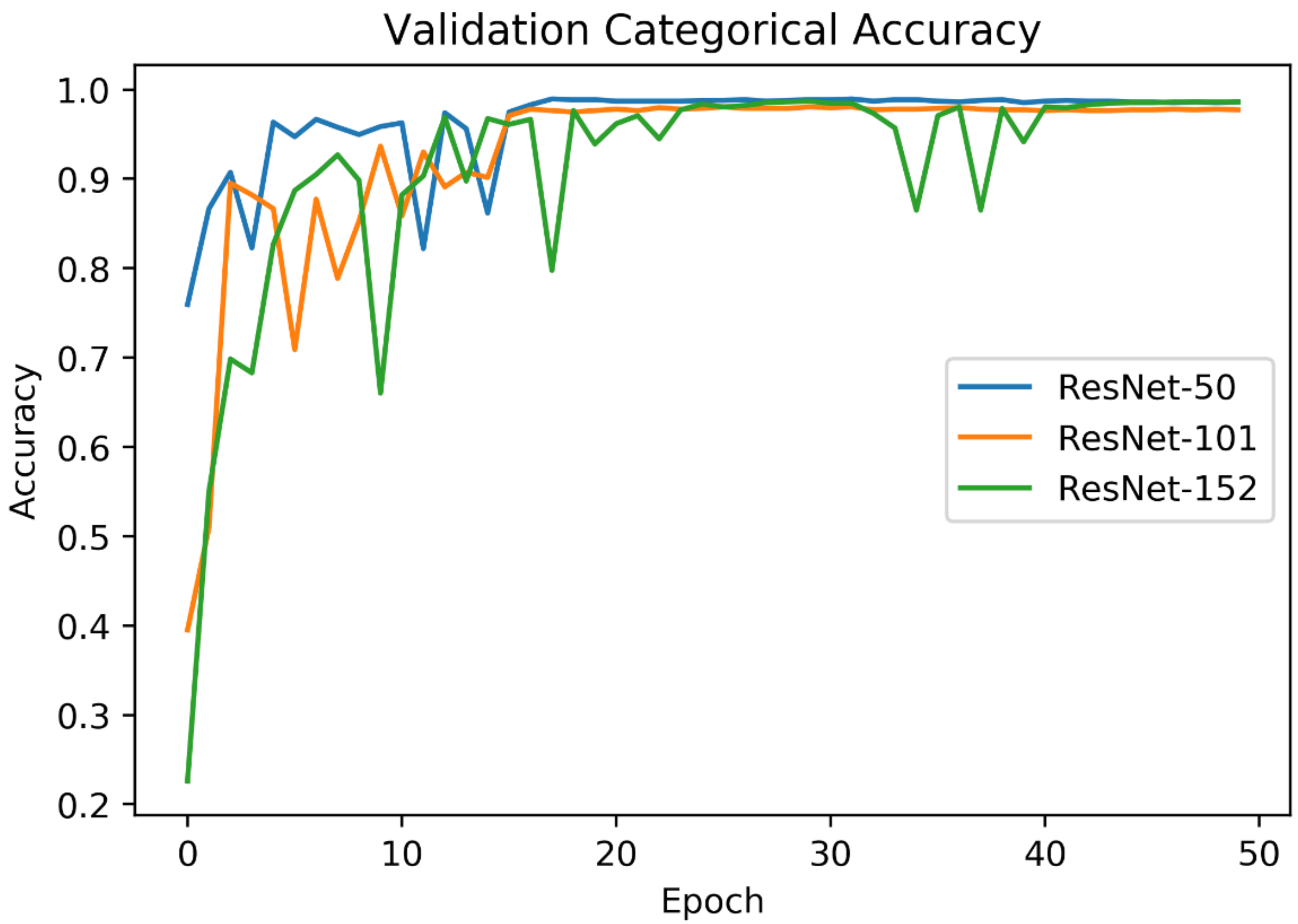


Goal post
(T-Line)

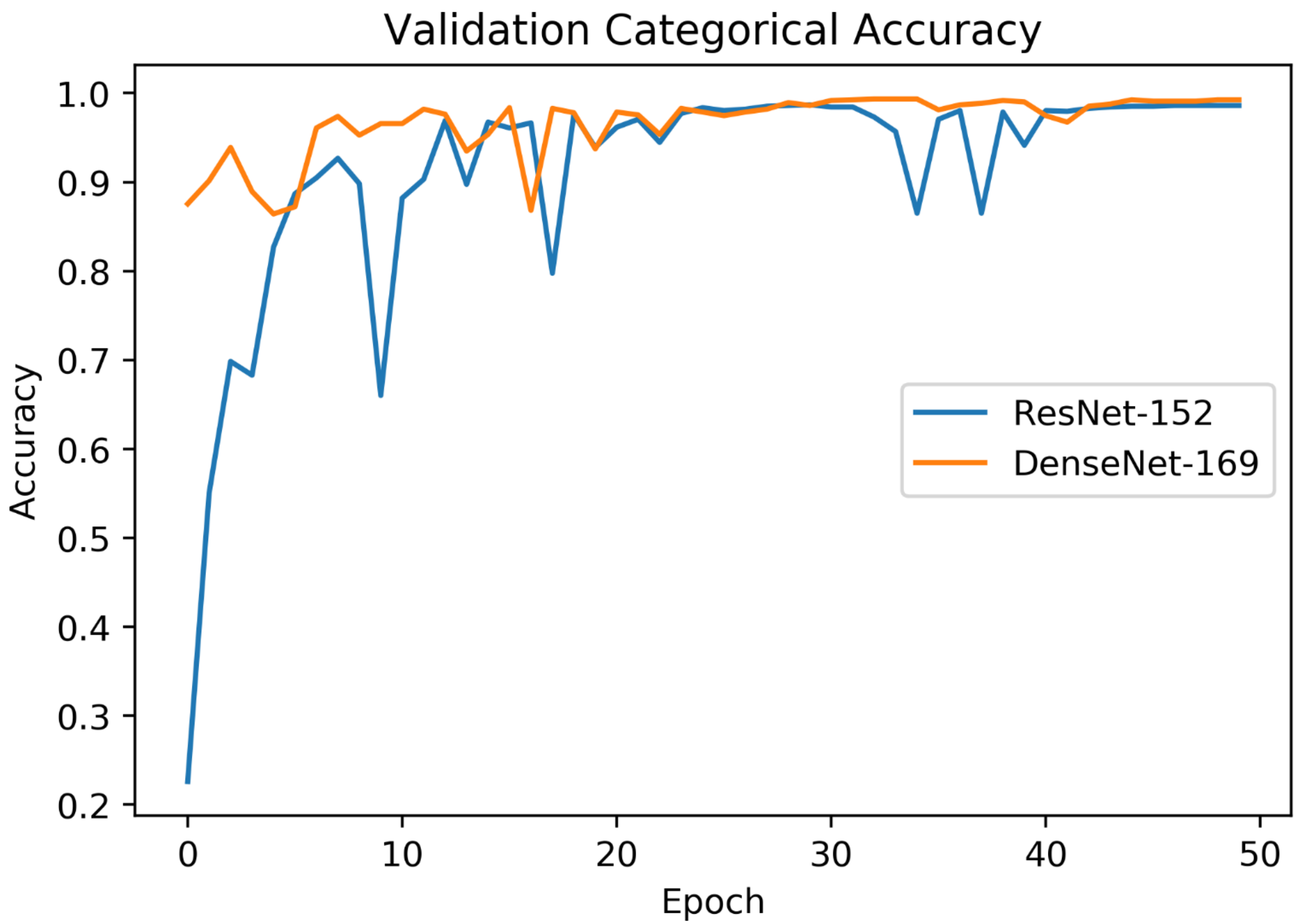
Penalty spot

Obstacle
(Robot foot)

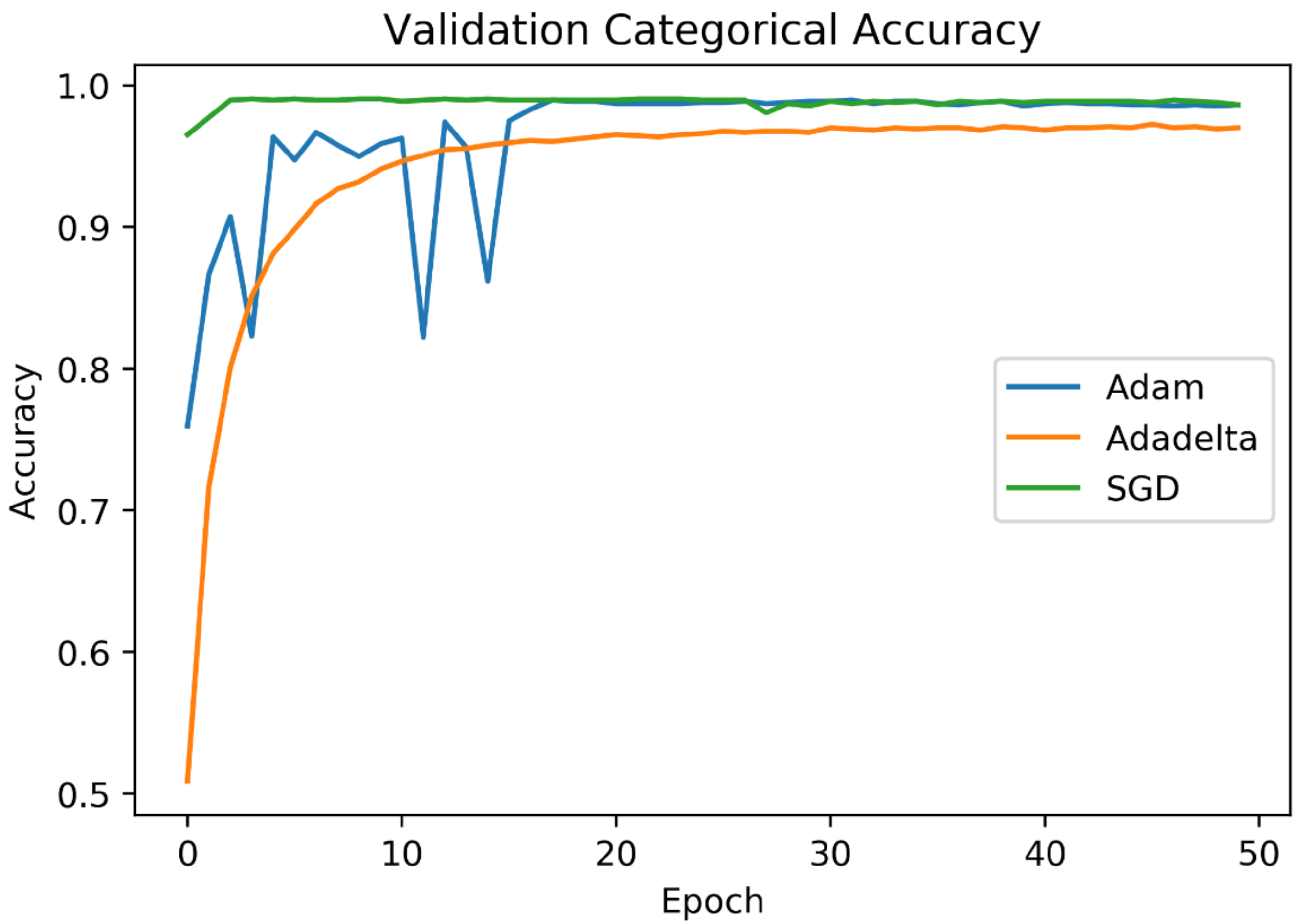
ResNet-50 -101 - 152



ResNet-152 & DenseNet-169



Optimizers


Validation Categorical Accuracy
Accuracy
1.0
0.9
0.8
0.7
0.6
0.5
0
10
20
30
40
50
Epoch
Adam
Adadelta
SGD

Summary

- **Deeper networks are trainable**
  - ResNet: through skip connections
  - DenseNet: through many skip connections in dense units
- **Skip connections allow the gradients to flow better**
  - Skip connections „artificially flatten the network“ such that deeper models are trainable
- **DenseNet improves ResNet**
  - Better information flow (concatenation of feature maps)
  - Even more deeper networks possible (many skip connections in dense blocks)
  - Less parmeters to learn (less filters per convolution layer)
  - Better accuracy

Literature

- Colab Notebook:

  https://github.com/abieren/DL-Seminar-ResNet-DenseNet

- Source code and documentation:

  Keras ResNet Documentation
  https://keras.io/applications/#resnet

  “Tutorial Keras: Transfer Learning with ResNet50”
  https://www.kaggle.com/suniliitb96/tutorial-keras-transfer-learning-with-resnet50

  GitHub: „How to add and remove new layers in keras after loading weights?”
  https://stackoverflow.com/questions/41668813/how-to-add-and-remove-new-layers-in-keras-after-loading-weights

- ResNet Paper:
  „Deep Residual Learning for Image Recognition”
  https://arxiv.org/abs/1512.03385

- DenseNet Paper:
  „Densely Connected Convolutional Networks“
  https://arxiv.org/abs/1608.06993

- Sweaty HS Offenburg:

  https://sweaty.hs-offenburg.de/projekt/