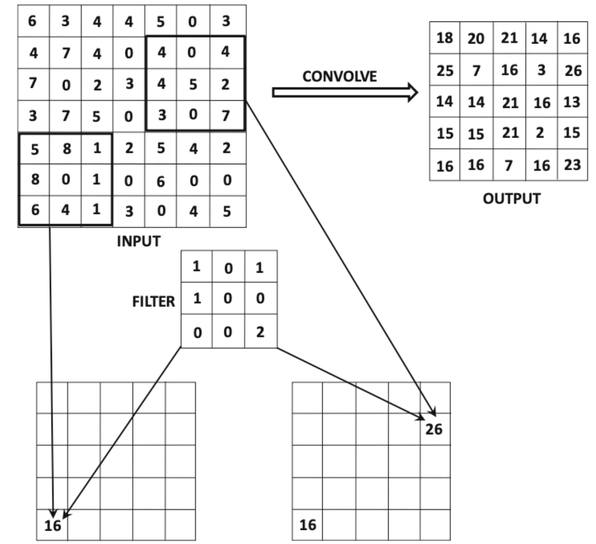
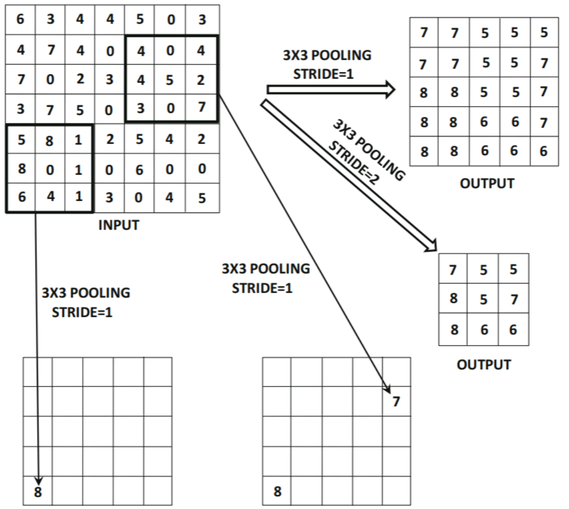
29-08-2024

Convolutional neural network (CNN)

- Convolution operation
  - Filters
  - 2-D convolution?
  - 3-D convolution ?
  - Padding
    - Zero or duplicate border values
  - Stride
    - Shift the convolution operations
    - 1, 2 not higher!
    - Depends on the filter size?
  - Bias
- ReLU
- Pooling
  - Max
  - Average
  - Simply down sample



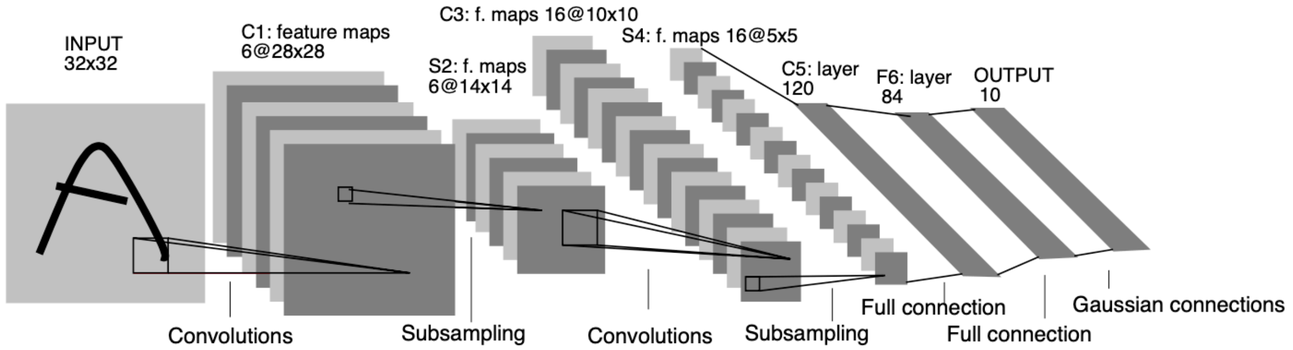


CNN (Cont…)

- Convolution operation
- ReLU
- Pooling
- Fully connected layers
  - Multi-layer perceptron

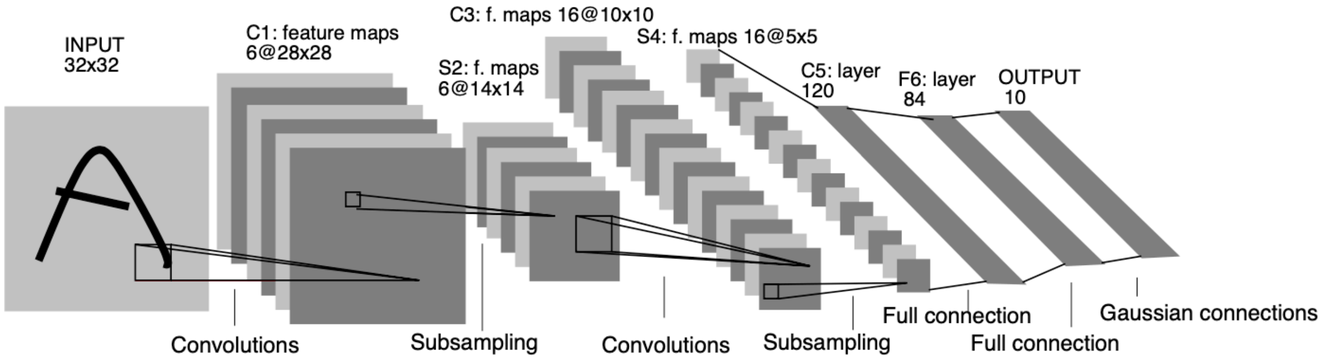
Feature detectors

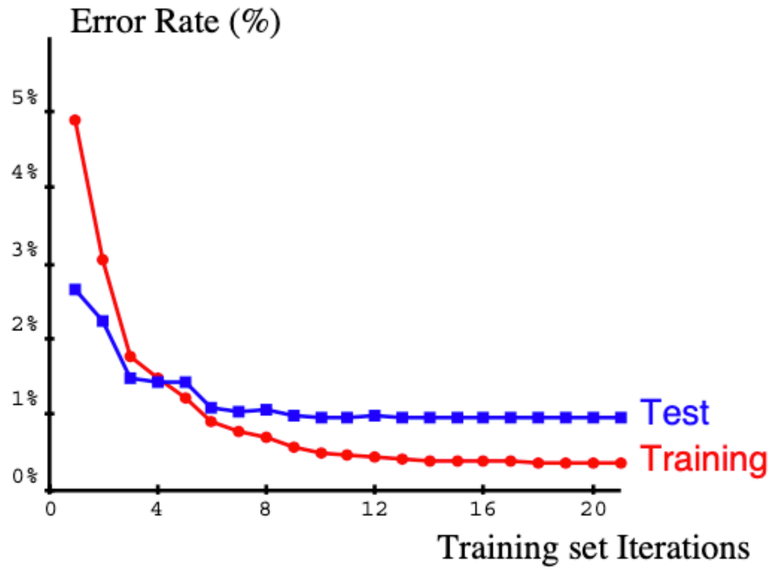
Classifier



LeNet-5

- LeNet-5: 1998
  - #parameters: 61,706



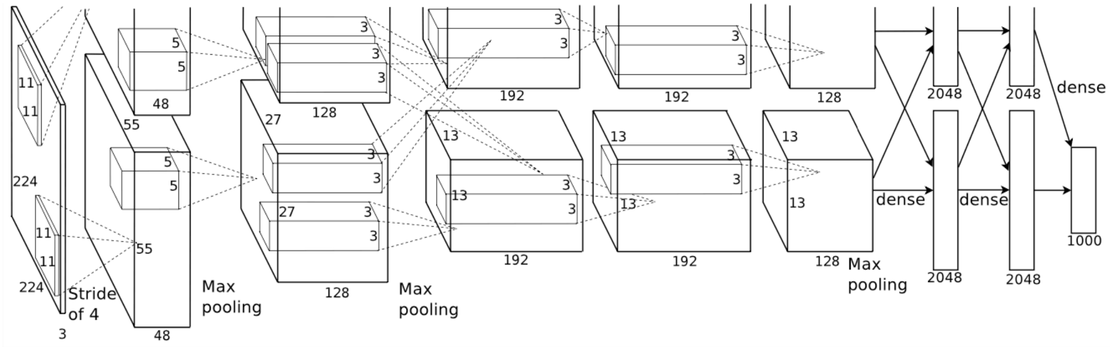



```
----------------------------------------------------------------
Network architechture (num chanel-1, num class- 10) as follows:
----------------------------------------------------------------
LeNet5(
  (features_detector): Sequential(
    (0): Conv2d(1, 6, kernel_size=(5, 5), stride=(1, 1))
    (1): AvgPool2d(kernel_size=2, stride=2, padding=0)
    (2): Sigmoid()
    (3): Conv2d(6, 16, kernel_size=(5, 5), stride=(1, 1))
    (4): AvgPool2d(kernel_size=2, stride=2, padding=0)
    (5): Sigmoid()
  )
  (classifier): Sequential(
    (0): Linear(in_features=400, out_features=120, bias=True)
    (1): Sigmoid()
    (2): Linear(in_features=120, out_features=84, bias=True)
    (3): Sigmoid()
    (4): Linear(in_features=84, out_features=10, bias=True)
  )
)
----------------------------------------------------------------
Network summary:
----------------------------------------------------------------
----------------------------------------------------------------
        Layer (type)               Output Shape         Param #
================================================================
            Conv2d-1           [-1, 6, 28, 28]             156
         AvgPool2d-2           [-1, 6, 14, 14]               0
           Sigmoid-3           [-1, 6, 14, 14]               0
            Conv2d-4          [-1, 16, 10, 10]           2,416
         AvgPool2d-5            [-1, 16, 5, 5]               0
           Sigmoid-6            [-1, 16, 5, 5]               0
            Linear-7                 [-1, 120]          48,120
           Sigmoid-8                 [-1, 120]               0
            Linear-9                  [-1, 84]          10,164
          Sigmoid-10                  [-1, 84]               0
           Linear-11                  [-1, 10]             850
================================================================
Total params: 61,706
```

Source: http://yann.lecun.com/exdb/publis/pdf/lecun-98.pdf

AlexNet

- Breakthrough in ML, 2012
  - Error: 16.4
  - #parameters: 60,000,000




```
----------------------------------------------------------
Network architechture (num channels=1, num classes= 10) as follows:
----------------------------------------------------------
AlexNetR(
  (features): Sequential(
    (0): Conv2d(1, 64, kernel_size=(11, 11), stride=(4, 4), padding=(2, 2))
    (1): ReLU(inplace=True)
    (2): MaxPool2d(kernel_size=3, stride=2, padding=0, dilation=1, ceil_mode=False)
    (3): Conv2d(64, 192, kernel_size=(5, 5), stride=(1, 1), padding=(2, 2))
    (4): ReLU(inplace=True)
    (5): MaxPool2d(kernel_size=3, stride=2, padding=0, dilation=1, ceil_mode=False)
    (6): Conv2d(192, 384, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (7): ReLU(inplace=True)
    (8): Conv2d(384, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (9): ReLU(inplace=True)
    (10): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (11): ReLU(inplace=True)
    (12): MaxPool2d(kernel_size=3, stride=2, padding=0, dilation=1, ceil_mode=False)
  )
  (avgpool): AdaptiveAvgPool2d(output_size=(6, 6))
  (classifier): Sequential(
    (0): Dropout(p=0.5, inplace=False)
    (1): Linear(in_features=9216, out_features=4096, bias=True)
    (2): ReLU(inplace=True)
    (3): Dropout(p=0.5, inplace=False)
    (4): Linear(in_features=4096, out_features=4096, bias=True)
    (5): ReLU(inplace=True)
    (6): Linear(in_features=4096, out_features=10, bias=True)
  )
)
----------------------------------------------------------
Network summary:
----------------------------------------------------------
==========================================================================================
Layer (type:depth-idx)                   Output Shape              Param #
==========================================================================================
├─Sequential: 1-1                        [-1, 256, 6, 6]           --
|    └─Conv2d: 2-1                       [-1, 64, 56, 56]          7,808
|    └─ReLU: 2-2                         [-1, 64, 56, 56]          --
|    └─MaxPool2d: 2-3                    [-1, 64, 27, 27]          --
|    └─Conv2d: 2-4                       [-1, 192, 27, 27]         307,392
|    └─ReLU: 2-5                         [-1, 192, 27, 27]         --
|    └─MaxPool2d: 2-6                    [-1, 192, 13, 13]         --
|    └─Conv2d: 2-7                       [-1, 384, 13, 13]         663,936
|    └─ReLU: 2-8                         [-1, 384, 13, 13]         --
|    └─Conv2d: 2-9                       [-1, 256, 13, 13]         884,992
|    └─ReLU: 2-10                        [-1, 256, 13, 13]         --
|    └─Conv2d: 2-11                      [-1, 256, 13, 13]         590,080
|    └─ReLU: 2-12                        [-1, 256, 13, 13]         --
|    └─MaxPool2d: 2-13                   [-1, 256, 6, 6]           --
├─AdaptiveAvgPool2d: 1-2                 [-1, 256, 6, 6]           --
├─Sequential: 1-3                        [-1, 10]                  --
|    └─Dropout: 2-14                     [-1, 9216]                --
|    └─Linear: 2-15                      [-1, 4096]                37,752,832
|    └─ReLU: 2-16                        [-1, 4096]                --
|    └─Dropout: 2-17                     [-1, 4096]                --
|    └─Linear: 2-18                      [-1, 4096]                16,781,312
|    └─ReLU: 2-19                        [-1, 4096]                --
|    └─Linear: 2-20                      [-1, 10]                  40,970
==========================================================================================
Total params: 57,029,322
```

Source: Alex Krizhevsky, Ilya Sutskever, Geoffrey E. Hinton, ImageNet Classification with Deep Convolutional Neural Networks, NIPS, 2012

VggNet

- VggNet: 2015
  - Error: 7.3%
  - #parameters: 140,000,000

ConvNet Configuration					
A	A-LRN	B	C	D	E
11 weight layers	11 weight layers	13 weight layers	16 weight layers	16 weight layers	19 weight layers
input (224 × 224 RGB image)					
conv3-64	conv3-64 **LRN**	conv3-64 **conv3-64**	conv3-64 conv3-64	conv3-64 conv3-64	conv3-64 conv3-64
maxpool					
conv3-128	conv3-128	conv3-128 **conv3-128**	conv3-128 conv3-128	conv3-128 conv3-128	conv3-128 conv3-128
maxpool					
conv3-256 conv3-256	conv3-256 conv3-256	conv3-256 conv3-256	conv3-256 conv3-256 **conv1-256**	conv3-256 conv3-256 **conv3-256**	conv3-256 conv3-256 conv3-256 **conv3-256**
maxpool					
conv3-512 conv3-512	conv3-512 conv3-512	conv3-512 conv3-512	conv3-512 conv3-512 **conv1-512**	conv3-512 conv3-512 **conv3-512**	conv3-512 conv3-512 conv3-512 **conv3-512**
maxpool					
conv3-512 conv3-512	conv3-512 conv3-512	conv3-512 conv3-512	conv3-512 conv3-512 **conv1-512**	conv3-512 conv3-512 **conv3-512**	conv3-512 conv3-512 conv3-512 **conv3-512**
maxpool					
FC-4096					
FC-4096					
FC-1000					
soft-max					

Source: Karen Simonyan & Andrew Zisserman, ICLR, 2015

ResNet

- ResNet: 2015
  - Error: 3.6%
  - #parameters: 58,161,162

layer name	output size	18-layer	34-layer	50-layer	101-layer	152-layer
conv1	112×112	7×7, 64, stride 2				
conv2_x	56×56	3×3 max pool, stride 2				
		$\begin{bmatrix} 3\times3, 64 \\ 3\times3, 64 \end{bmatrix}\times2$	$\begin{bmatrix} 3\times3, 64 \\ 3\times3, 64 \end{bmatrix}\times3$	$\begin{bmatrix} 1\times1, 64 \\ 3\times3, 64 \\ 1\times1, 256 \end{bmatrix}\times3$	$\begin{bmatrix} 1\times1, 64 \\ 3\times3, 64 \\ 1\times1, 256 \end{bmatrix}\times3$	$\begin{bmatrix} 1\times1, 64 \\ 3\times3, 64 \\ 1\times1, 256 \end{bmatrix}\times3$
conv3_x	28×28	$\begin{bmatrix} 3\times3, 128 \\ 3\times3, 128 \end{bmatrix}\times2$	$\begin{bmatrix} 3\times3, 128 \\ 3\times3, 128 \end{bmatrix}\times4$	$\begin{bmatrix} 1\times1, 128 \\ 3\times3, 128 \\ 1\times1, 512 \end{bmatrix}\times4$	$\begin{bmatrix} 1\times1, 128 \\ 3\times3, 128 \\ 1\times1, 512 \end{bmatrix}\times4$	$\begin{bmatrix} 1\times1, 128 \\ 3\times3, 128 \\ 1\times1, 512 \end{bmatrix}\times8$
conv4_x	14×14	$\begin{bmatrix} 3\times3, 256 \\ 3\times3, 256 \end{bmatrix}\times2$	$\begin{bmatrix} 3\times3, 256 \\ 3\times3, 256 \end{bmatrix}\times6$	$\begin{bmatrix} 1\times1, 256 \\ 3\times3, 256 \\ 1\times1, 1024 \end{bmatrix}\times6$	$\begin{bmatrix} 1\times1, 256 \\ 3\times3, 256 \\ 1\times1, 1024 \end{bmatrix}\times23$	$\begin{bmatrix} 1\times1, 256 \\ 3\times3, 256 \\ 1\times1, 1024 \end{bmatrix}\times36$
conv5_x	7×7	$\begin{bmatrix} 3\times3, 512 \\ 3\times3, 512 \end{bmatrix}\times2$	$\begin{bmatrix} 3\times3, 512 \\ 3\times3, 512 \end{bmatrix}\times3$	$\begin{bmatrix} 1\times1, 512 \\ 3\times3, 512 \\ 1\times1, 2048 \end{bmatrix}\times3$	$\begin{bmatrix} 1\times1, 512 \\ 3\times3, 512 \\ 1\times1, 2048 \end{bmatrix}\times3$	$\begin{bmatrix} 1\times1, 512 \\ 3\times3, 512 \\ 1\times1, 2048 \end{bmatrix}\times3$
	1×1	average pool, 1000-d fc, softmax				
FLOPs		1.8×10^9	3.6×10^9	3.8×10^9	7.6×10^9	11.3×10^9

ResNet Architectures

Source: Hei et al., Deep Residual Learning for Image Recognition, CVPR 2016

How to train a CNN ?

- What is different from our MLP training?
- Let’s consider the operations in different layers?
  - Convolution
  - ReLU
  - Pooling
  - Fully connected layers