Machine Learning: CNNs

Outline

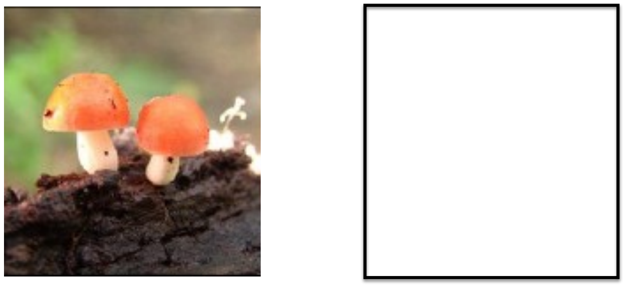
- Convolutional neural networks (CNNs)
  - why not use unstructured feed-forward models?
  - key parts: convolution, pooling
  - examples

Our problem: image classification

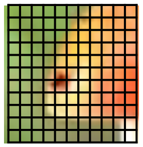
- E.g., image classification (1K categories)

Image	**Category**
	mushroom
	cherry
...	...

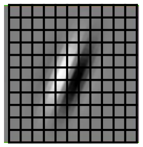
Feed-forward networks



Patch classifier/filter

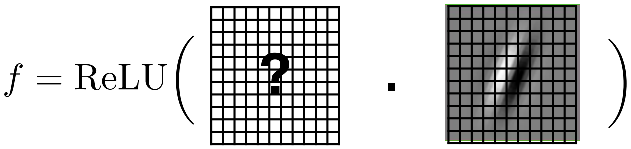


11x11
input



11x11
weights

Convolution



11x11
input

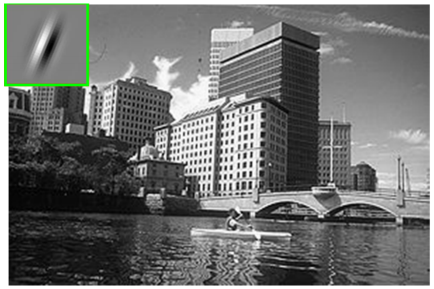
11x11
weights

input

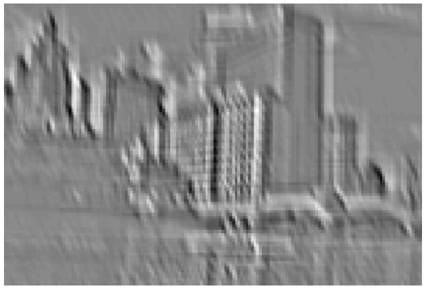
feature map

Convolution, feature map

filter
patch



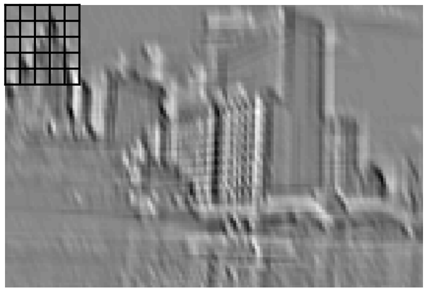
original image



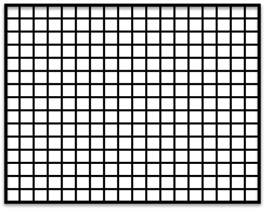
resulting feature map

Pooling

- We wish to know whether a feature was there but not exactly where it was



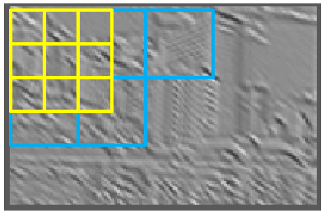
feature map



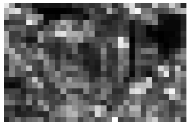
pooled map

Pooling (max)

- Pooling region and “stride” may vary
  - pooling induces translation invariance at the cost of spatial resolution
  - stride reduces the size of the resulting feature map

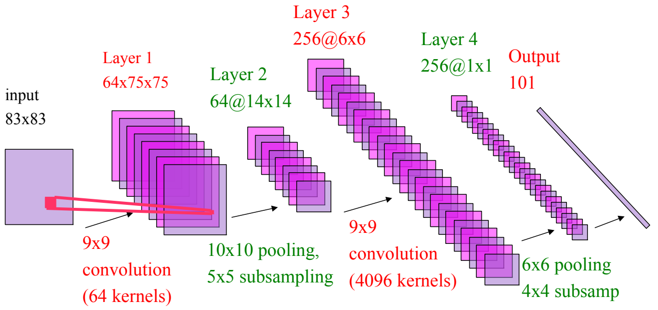


feature map



feature map
after max pooling

Convolutional Neural Network



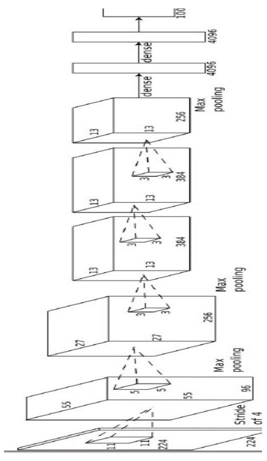
- Non-Linearity: half-wave rectification, shrinkage function, sigmoid
- Pooling: average, L1, L2, max
- Training: Supervised (1988-2006), Unsupervised+Supervised (2006-now)

(LeCun 13’)

Convolutional Neural Network

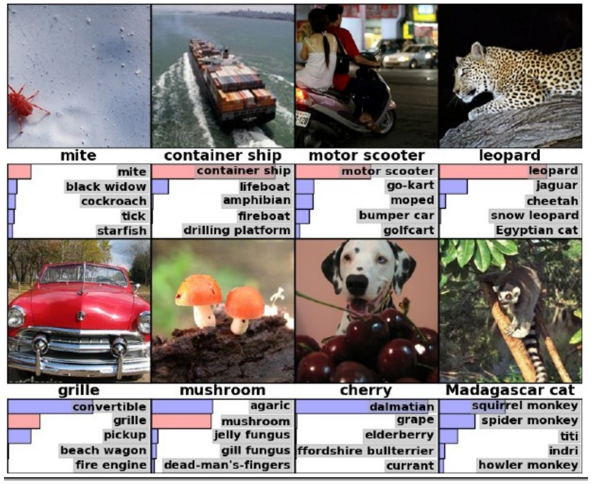
- 1000 categories, 1.5 Million labeled training samples
- Won the 2012 ImageNet LSVRC. 60 Million parameters, 832M MAC ops

4M	FULL CONNECT	4Mflop
16M	FULL 4096/ReLU	16M
37M	FULL 4096/ReLU	37M
	MAX POOLING	
442K	CONV 3x3/ReLU 256fm	74M
1.3M	CONV 3x3ReLU 384fm	224M
884K	CONV 3x3/ReLU 384fm	149M
	MAX POOLING 2x2sub	
	LOCAL CONTRAST NORM	
307K	CONV 11x11/ReLU 256fm	223M
	MAX POOL 2x2sub	
	LOCAL CONTRAST NORM	
35K	CONV 11x11/ReLU 96fm	105M



(Krizhevsky et al., 12’)

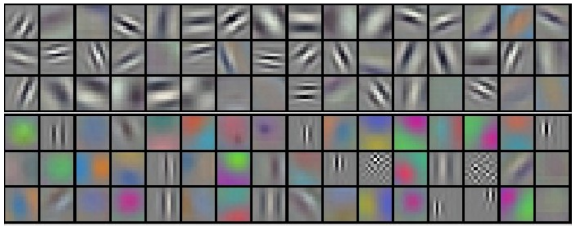
Convolutional Neural Network



(Krizhevsky et al., 12’)

ConvNet features

Learned layer 1 CNN filters



96 convolutional filters on the first layer
(filters are of size 11x11x3, applied across
input images of size 224x224x3)

(Krizhevsky et al., 12')