
Convnets
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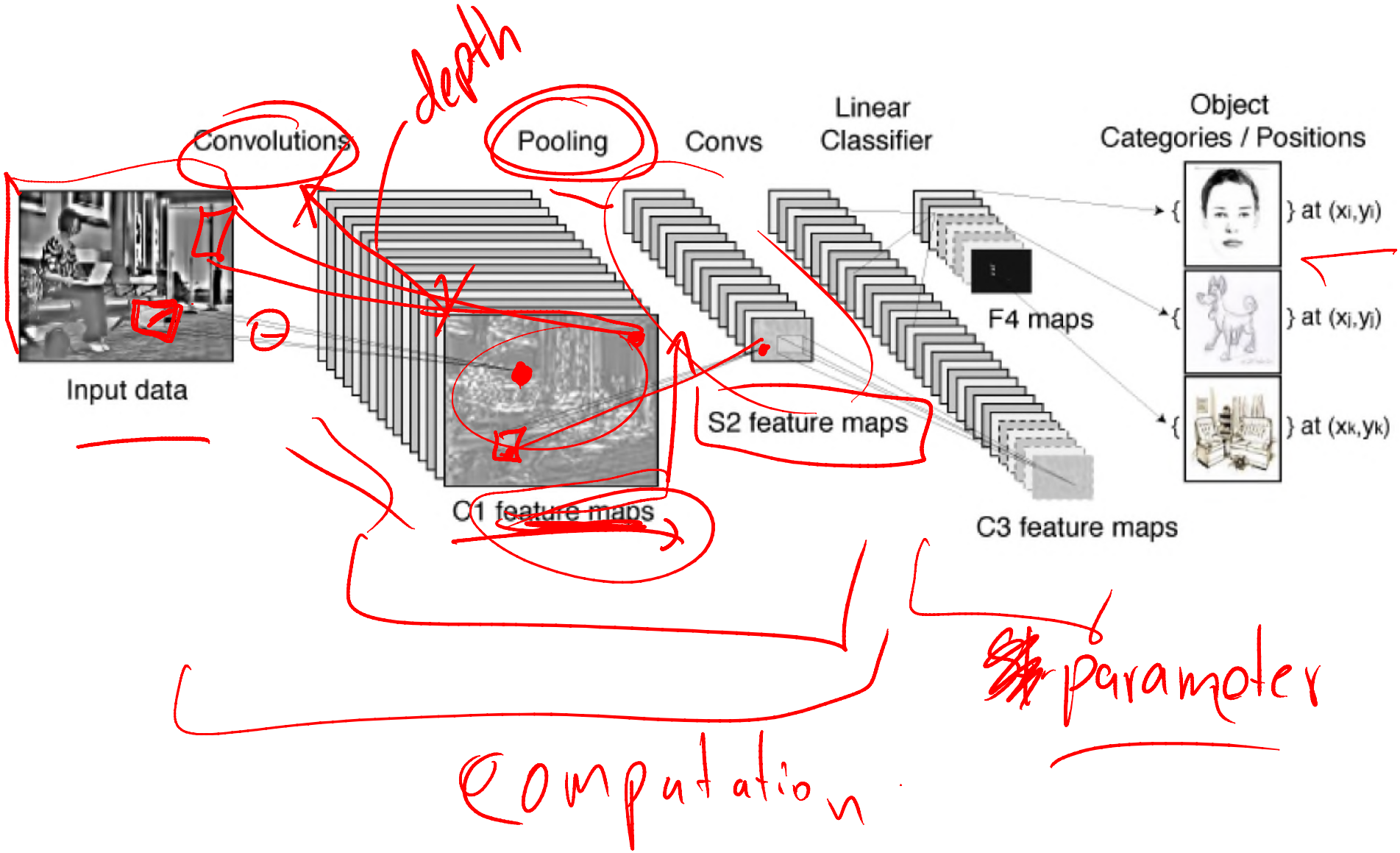
Outline of the lecture

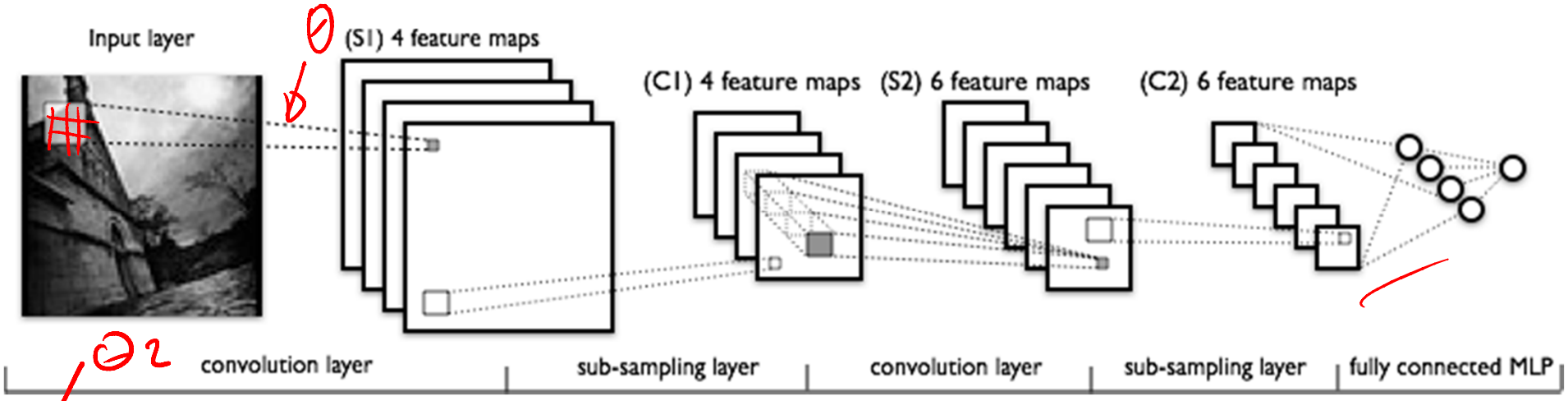
This lecture introduces you to convolutional neural networks. These models have revolutionized speech and object recognition. The goal is for you to learn

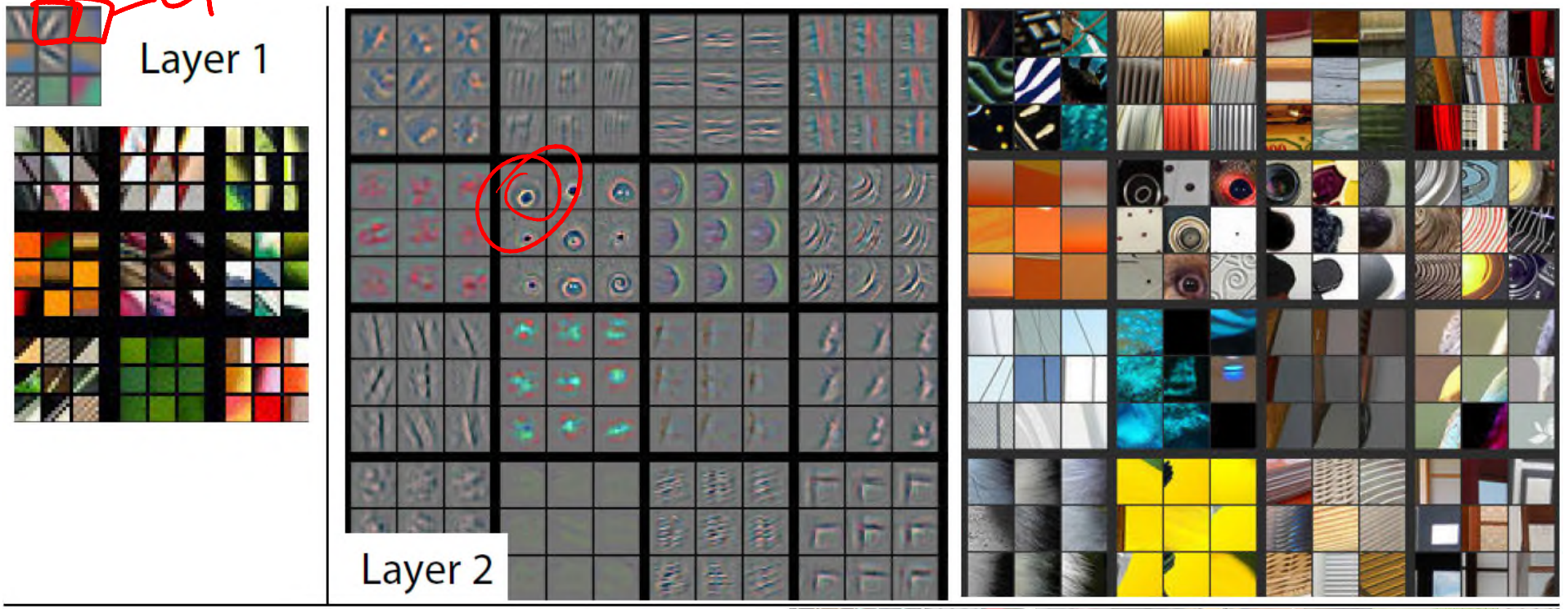
- ❑ Convnets for object recognition and language
- ❑ How to design convolutional layers
- ❑ How to design pooling layers
- ❑ How to build convnets in torch

Convnets (Fukushima, LeCun, Hinton)

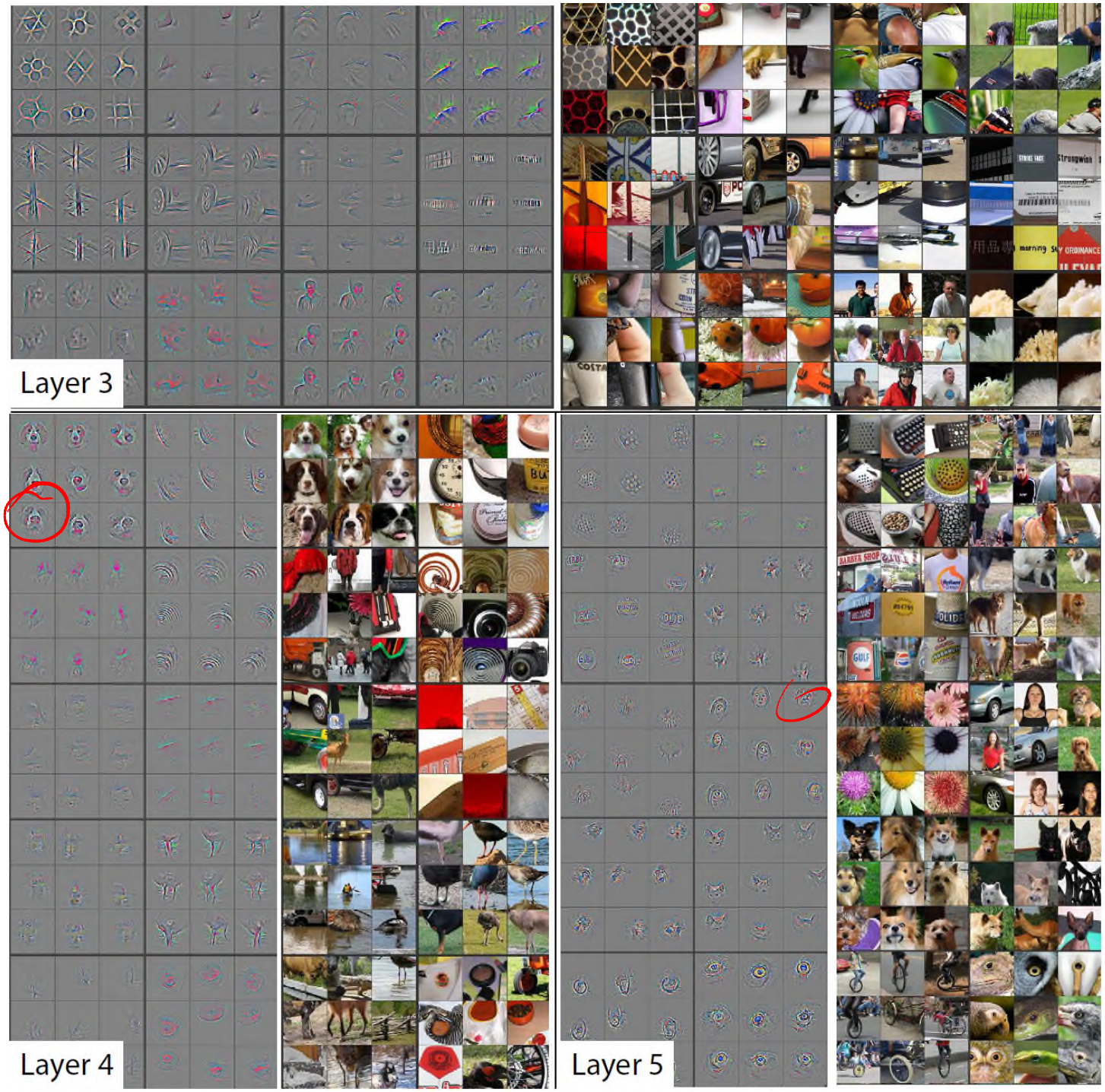


Convolutional networks

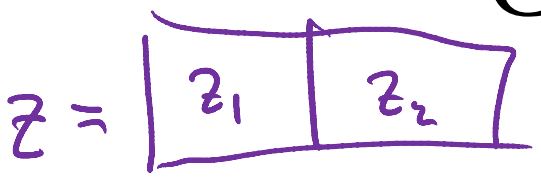


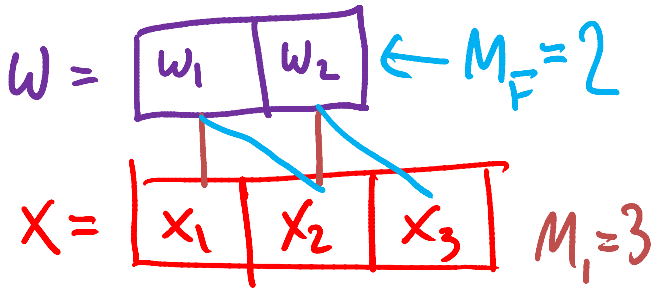


[Matthew Zeiler & Rob Fergus]

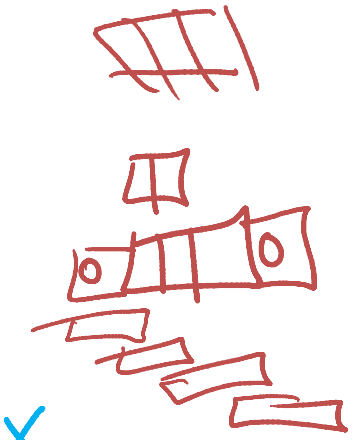

Layer 3
Layer 4
Layer 5

Convolution



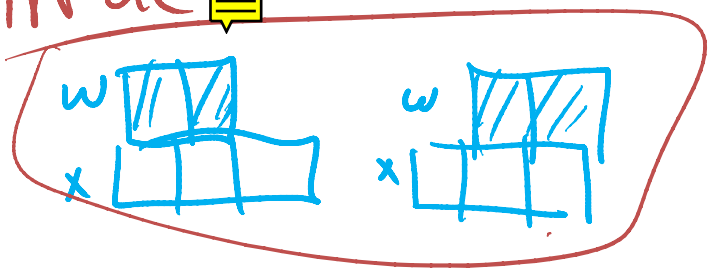


$$\begin{cases} z_1 = w_1 x_1 + w_2 x_2 \\ z_2 = w_1 x_2 + w_2 x_3 \end{cases}$$



zero padding

Stride



$$z_{i'} = \sum_{i=1}^{M_F=2} w_i x_{i'+i-1}$$

Correlation (similarity)

$$\| $$

$$z_{i'} = \sum_{i=1}^{M_F=2} x_{i'+i-1} \bar{w}_{M_F-i+1}$$

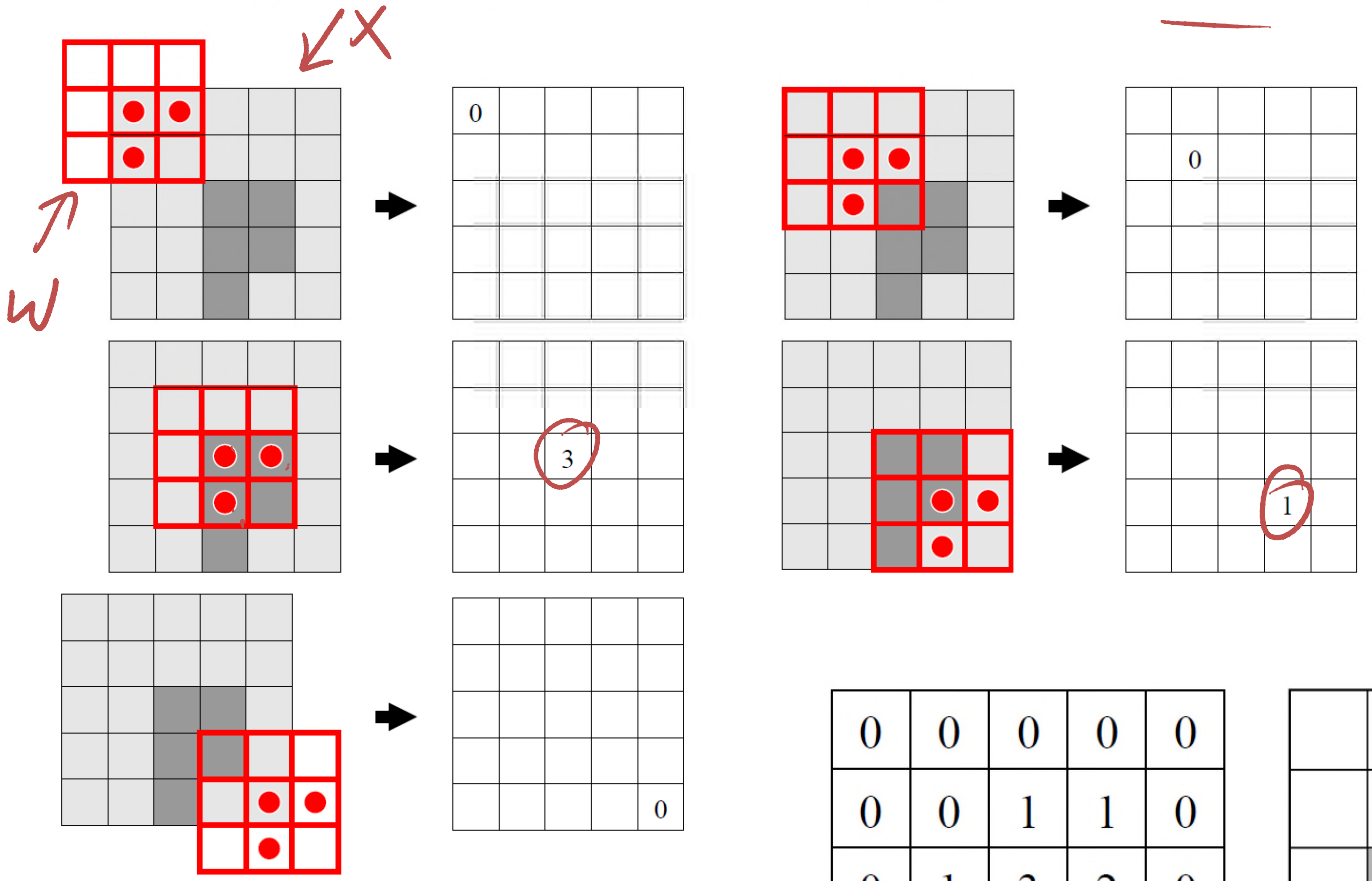
(convolution)

$\vec{w} \rightarrow$ flip $\rightarrow \bar{w}$ =

Andrej Karpathy

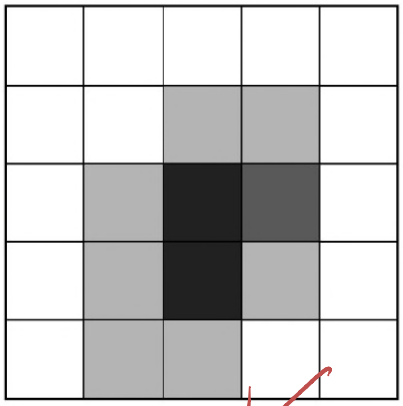
Image convolution

For the image, take dark pixel value = 1, light pixel value = 0.



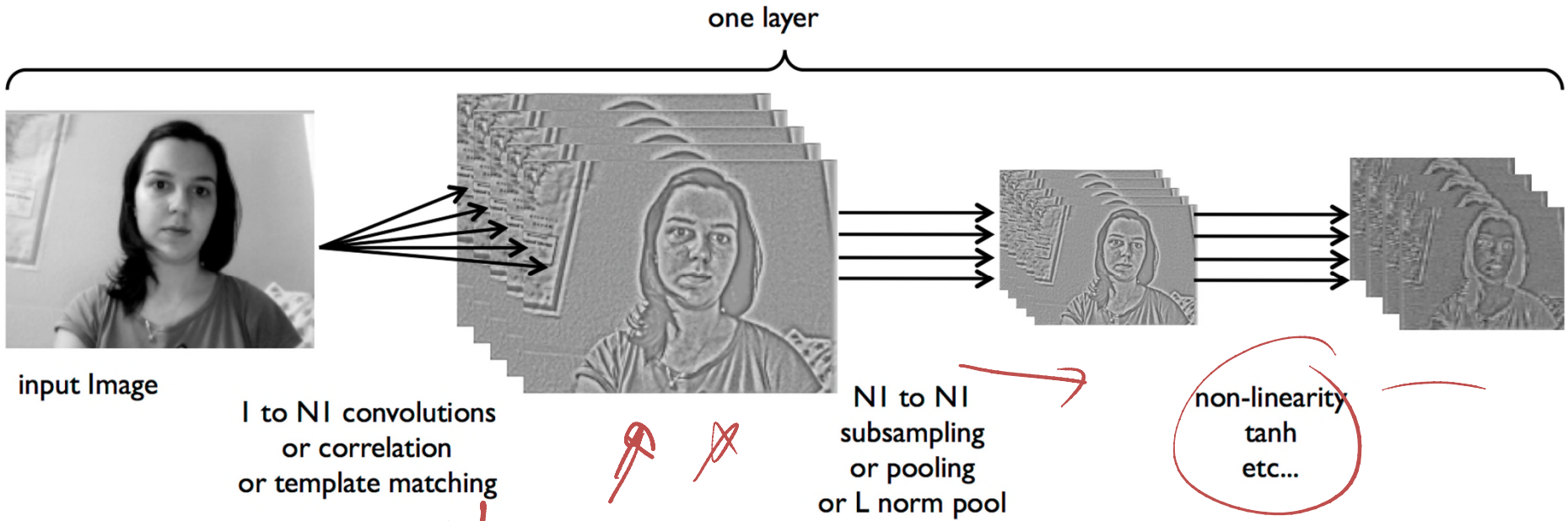
feature map

0	0	0	0	0
0	0	1	1	0
0	1	3	2	0
0	1	3	1	0
0	1	1	0	0



Leow Wee Kheng

Convnets (Fukushima, LeCun, Hinton)



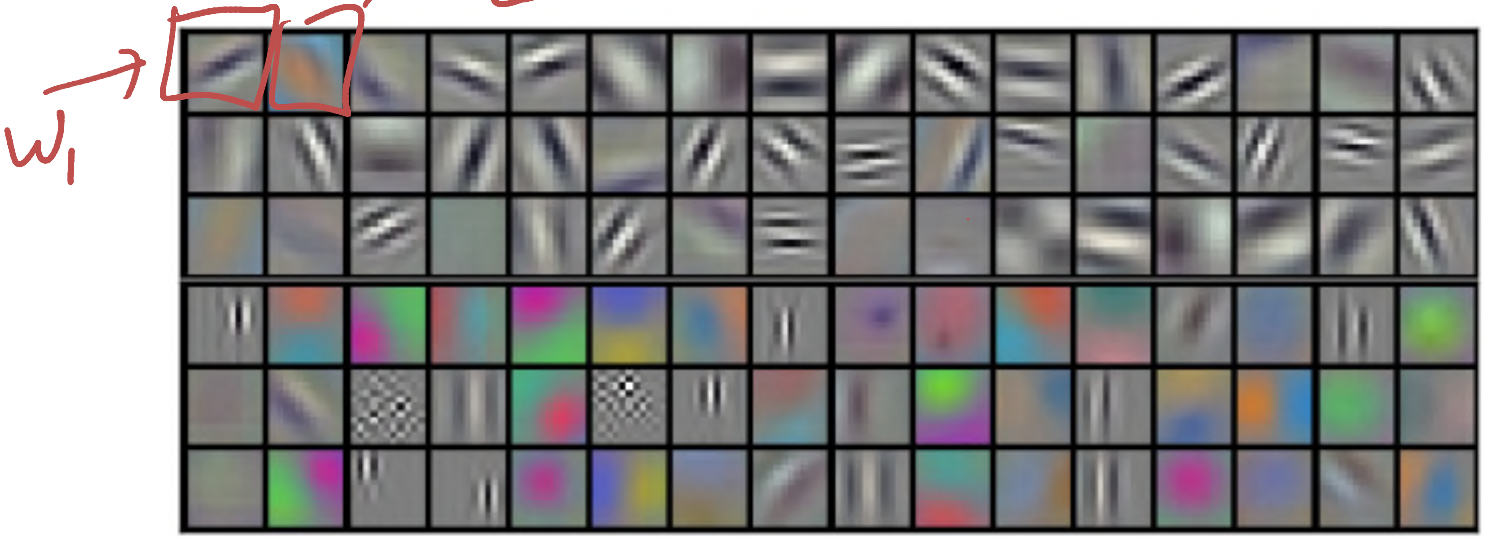
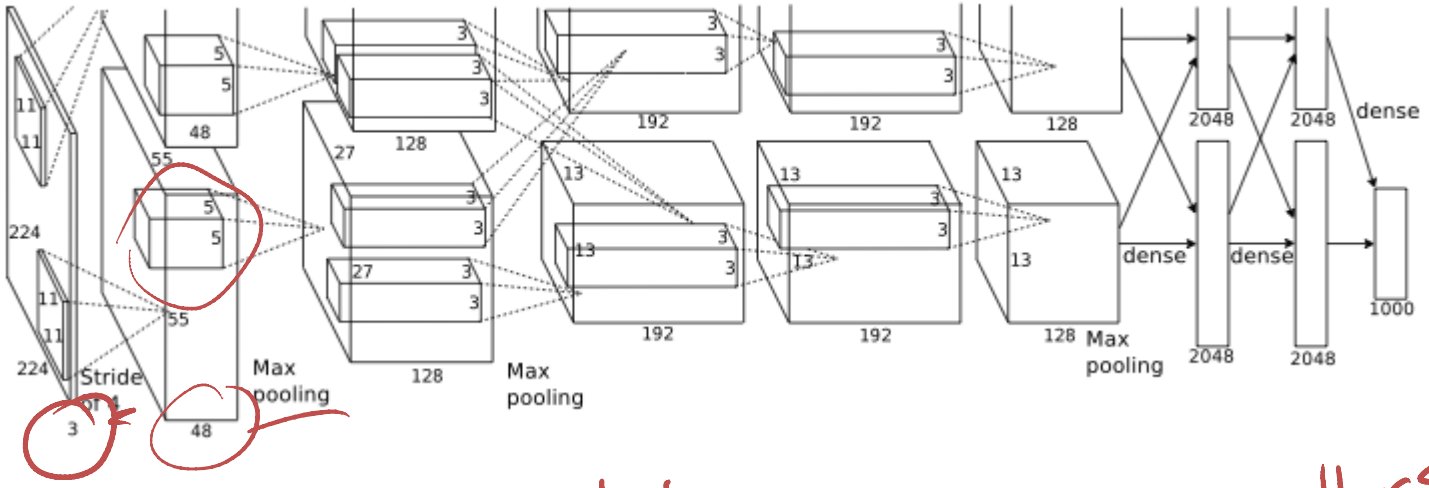


Image convolution layer



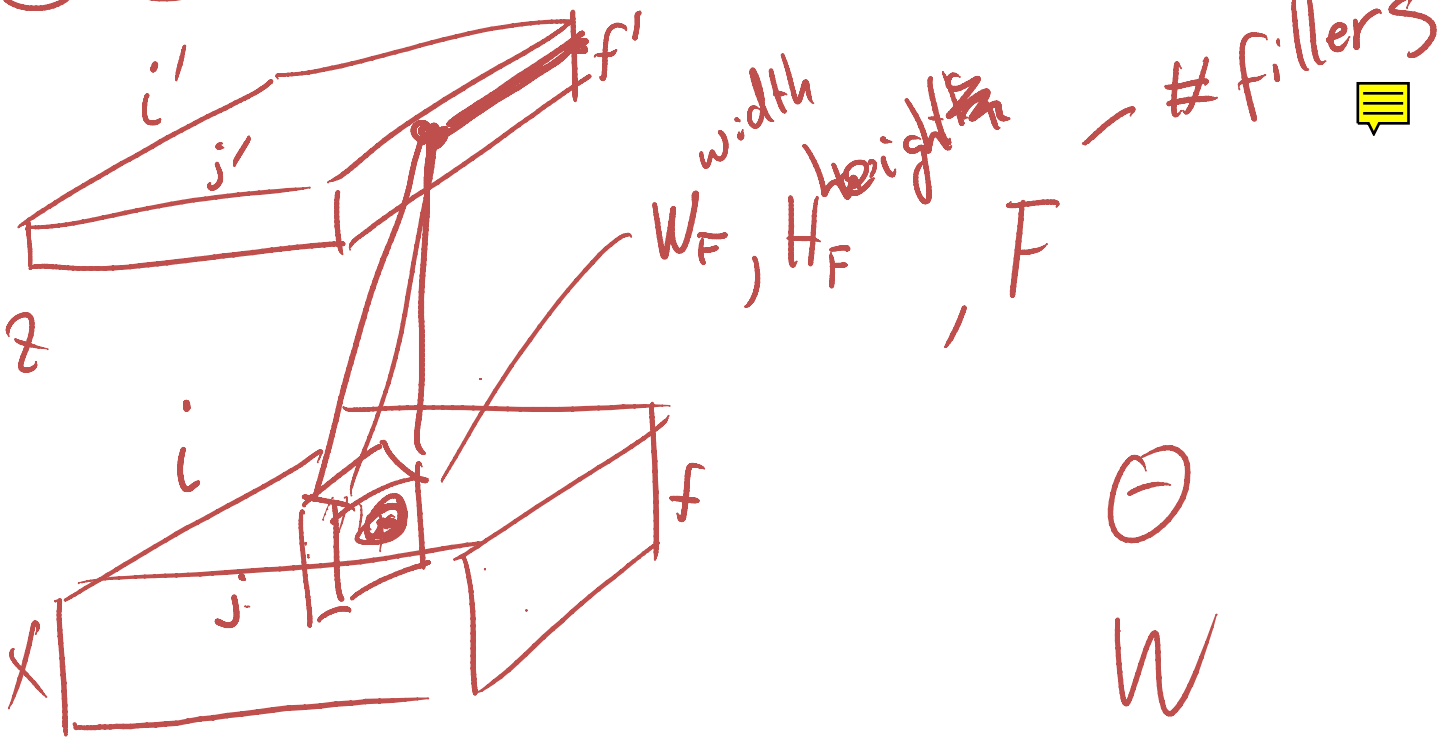
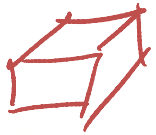
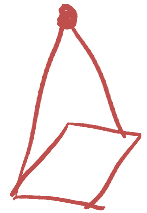


Image convolution layer





$$\mathbf{y}_{i',j',f'} = b_{f'} + \sum_{i=1}^{H_f} \sum_{j=1}^{W_f} \sum_{f=1}^{F} \mathbf{x}_{i'+i-1,j'+j-1,f} \boldsymbol{\theta}_{ijff'}$$

$$\frac{\partial E}{\partial \theta_{ijff'}} = \sum_{i'j'f'} \delta^{l+1}_{i'j'f'} \frac{\partial f_{i'j'f'}(\mathbf{x}; \boldsymbol{\theta}_{f'})}{\partial \theta_{ijff'}}$$

$$= \sum_{i'j'} \delta^{l+1}_{i'j'f'} \mathbf{x}_{i'+i-1,j'+j-1,f}$$

Image convolution layer

$$\mathbf{y}_{i',j',f'} = b_{f'} + \sum_{i''=1}^{H_f} \sum_{j''=1}^{W_f} \sum_{f''=1}^{F} \mathbf{x}_{i'+i''-1,j'+j''-1,f''} \boldsymbol{\theta}_{i''j''f''f'}$$

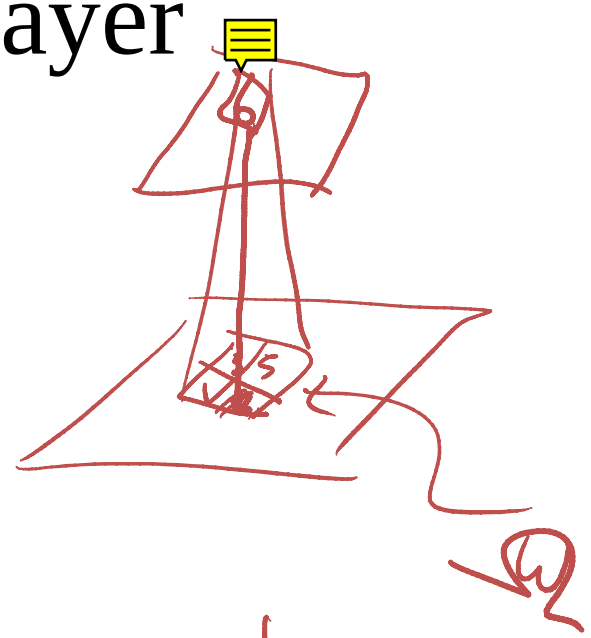
$$\delta^l_{ijf} = \sum_{i'j'f'} \delta^{l+1}_{i'j'f'} \frac{\partial f_{i'j'f'}(\mathbf{x}; \boldsymbol{\theta}_{f'})}{\partial \mathbf{x}_{ijf}}$$

$$i = i' + i'' - 1$$

$$i'' = i - i' + 1$$

$$= \sum_{i'j'f'} \delta^{l+1}_{i'j'f'} \theta_{i-i'+1,j-j'+1,f,f'}$$

Image max-pooling layer



$$\mathbf{y}_{i',j'} = \max_{ij \in \Omega(i'j')} \mathbf{x}_{ij}$$

$$\delta_{ij}^{l} = \sum_{i'j'} \delta_{i'j'}^{l+1} \frac{\partial f_{i'j'}(\mathbf{x})}{\partial \mathbf{x}_{ij}}$$

$$= \delta_{ij}^{l+1} \mathbb{I}_{ij = \arg\max_{i''j'' \in \Omega(i'j')} \mathbf{x}_{i''j''}}$$

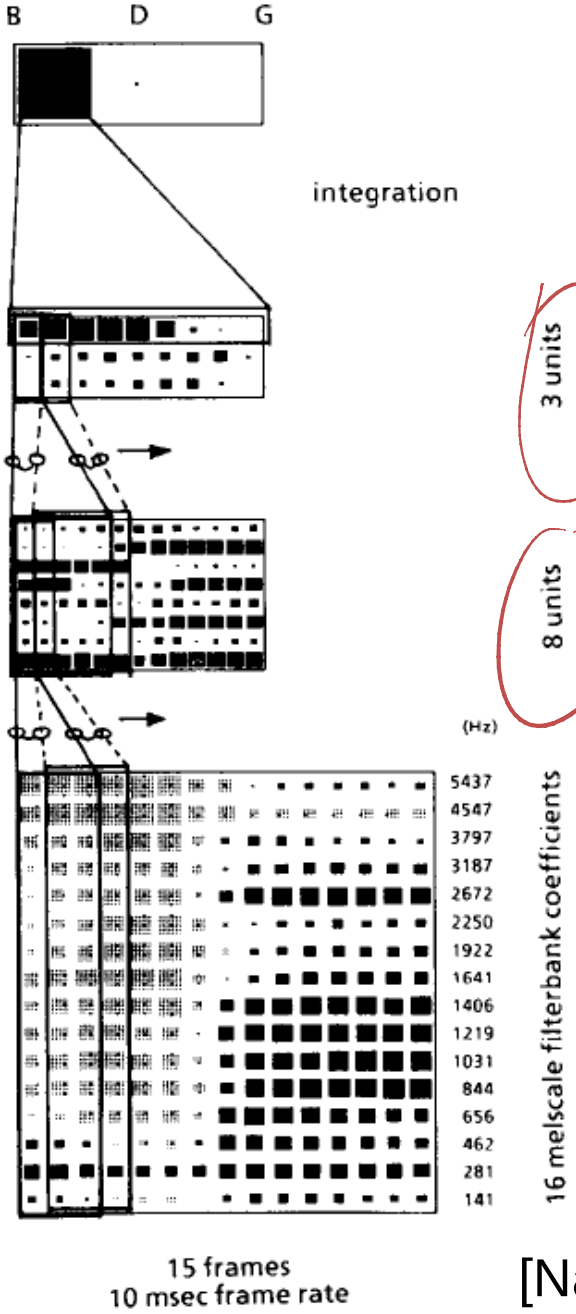
Capsules Draw

Convnets in Torch

Xavier Glorot

```
model = nn.Sequential()
model:add(nn.Reshape(1,32,32))
-- layer 1:
model:add(nn.SpatialConvolution(1, 16, 5, 5))
model:add(nn.Tanh())
model:add(nn.SpatialMaxPooling(2, 2, 2, 2))
-- layer 2:
model:add(nn.SpatialConvolution(16, 128, 5, 5))
model:add(nn.Tanh())
model:add(nn.SpatialMaxPooling(2, 2, 2, 2))
-- layer 3, a simple 2-layer neural net:
model:add(nn.Reshape(128*5*5))
model:add(nn.Linear(128*5*5, 200))
model:add(nn.Tanh())
model:add(nn.Linear(200,10))
model:add(nn.LogSoftMax())
```

ConvNets for Language



Leon Bottou

Phoneme Recognition Using Time-Delay Neural Networks

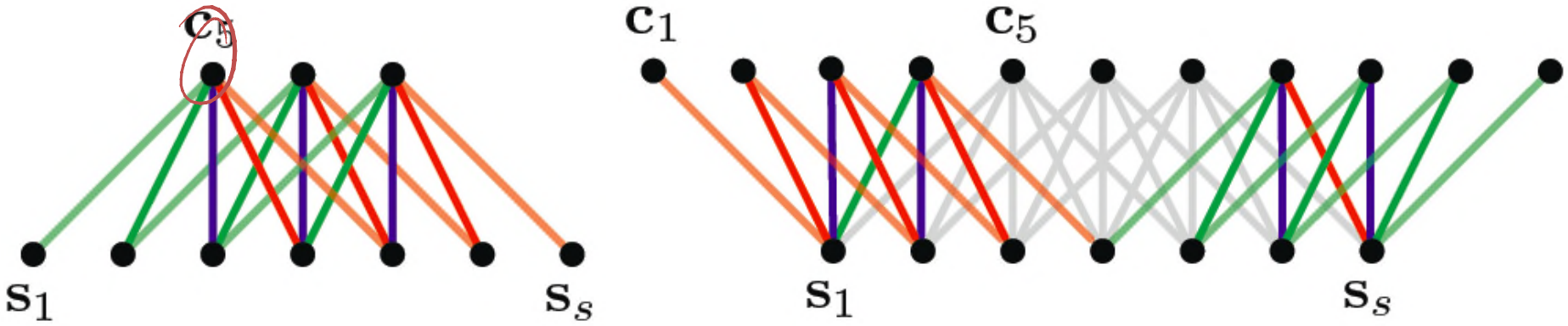
ALEXANDER WAIBEL, MEMBER, IEEE, TOSHIYUKI HANAZAWA, GEOFFREY HINTON, KIYOHIRO SHIKANO, MEMBER, IEEE, AND KEVIN J. LANG

NLP almost from scratch

→ [Ronan Collobert, Jason Weston, 2008]

[Nal Kalchbrenner, Ed Grefenstette, Phil Blunsom, 2014]

Sentence ConvNets



$$\mathbf{c}_j = \mathbf{m}^\intercal \mathbf{s}_{j-m+1:j}$$

$\mathbf{m}$ is the *filter* of the convolution

$$\mathbf{s} = \begin{bmatrix} | & | & | \\ \mathbf{w}_1 & \cdots & \mathbf{w}_s \\ | & | & | \end{bmatrix}$$

$$\mathbf{w}_i \in \mathbb{R}^d$$

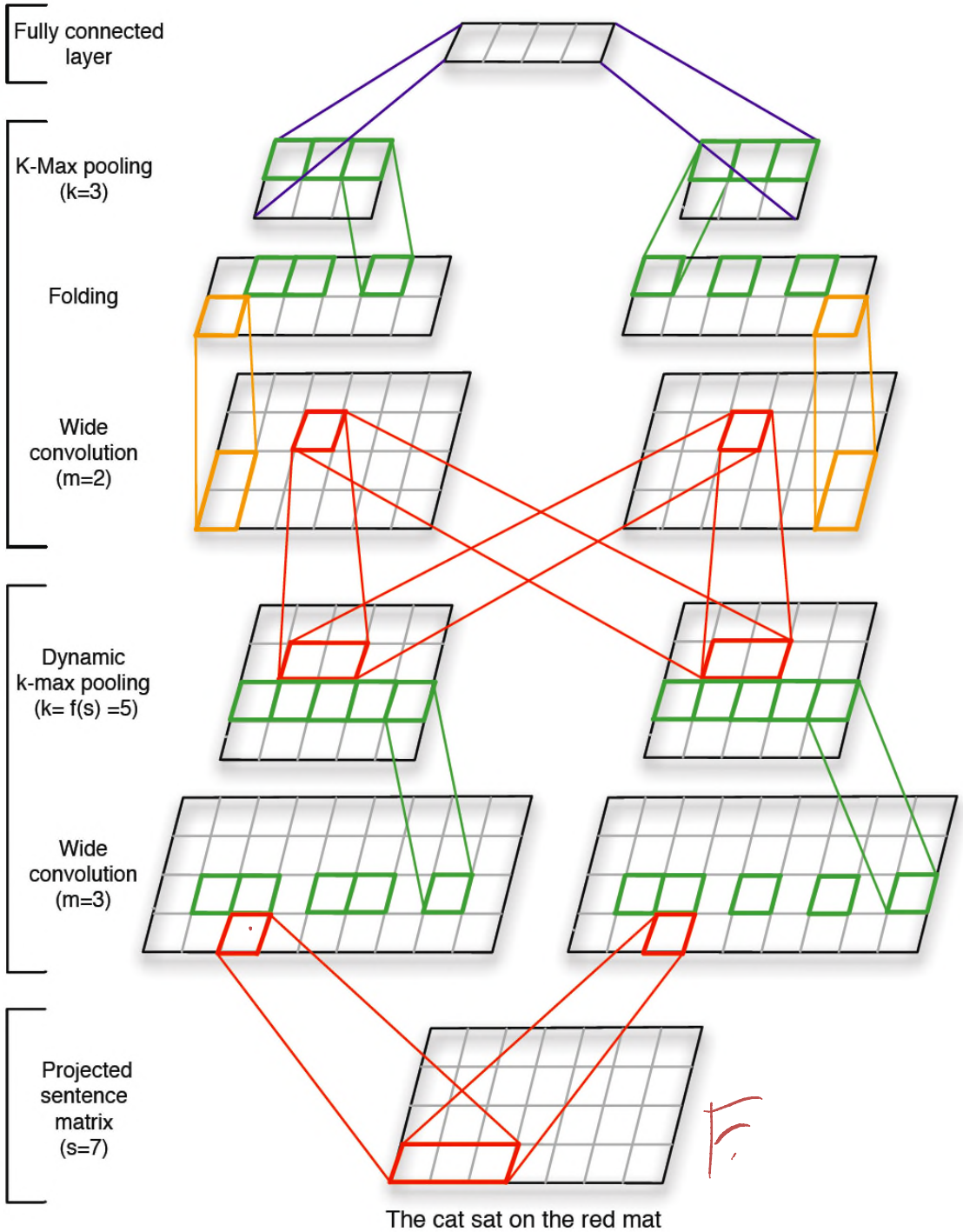
$$W_T \begin{bmatrix} w_1 & \cdots & w_s \end{bmatrix} \begin{bmatrix} 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

← cat

← one hot encoding

[Kalchbrenner, Grefenstette, Blunsom, 2014]

Sentence DynConvNet



[Kalchbrenner et al, 2014]

Document models (Misha Denil)