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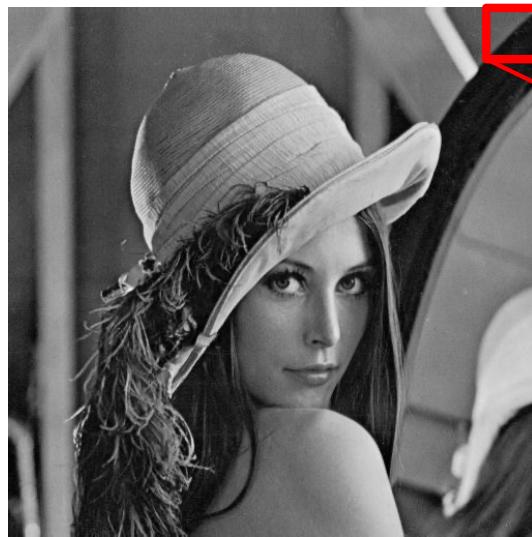
Deep Learning Applications for Computer Vision

Lecture 15: Convolutional Neural Networks

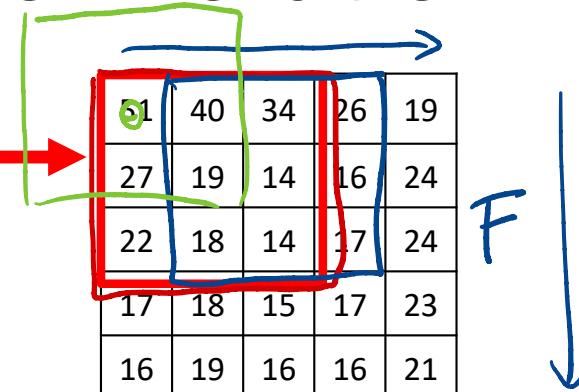


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Remember Convolution?



1	1	1
1	1	1
1	1	1



Notations:

- Kernel H - filter
- Original Image F
- New Image R

$$R_{ij} = \sum_{u,v} H_{i-u,j-v} F_{u,v}$$

$$\begin{aligned} 51 + 40 + 34 + 27 + 19 + 14 + \\ 22 + 18 + 14 = 239 \end{aligned}$$

$$239/9 = 26.555 \rightarrow 27$$

+	*	*	*	*
*	27	22	-	*
*	-	-	-	*
-	-	-	-	.

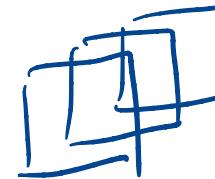


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Convolutions in Neural Networks

Convolutional Neural Networks:

- have hidden layers
- stacked convolutions/filters: a convolutional block
- detect patterns
 - simple patterns: edges, colors, simple shapes
 - specific object components: eyes, ears, fur, ..
- pass the output to the next (conv) layer

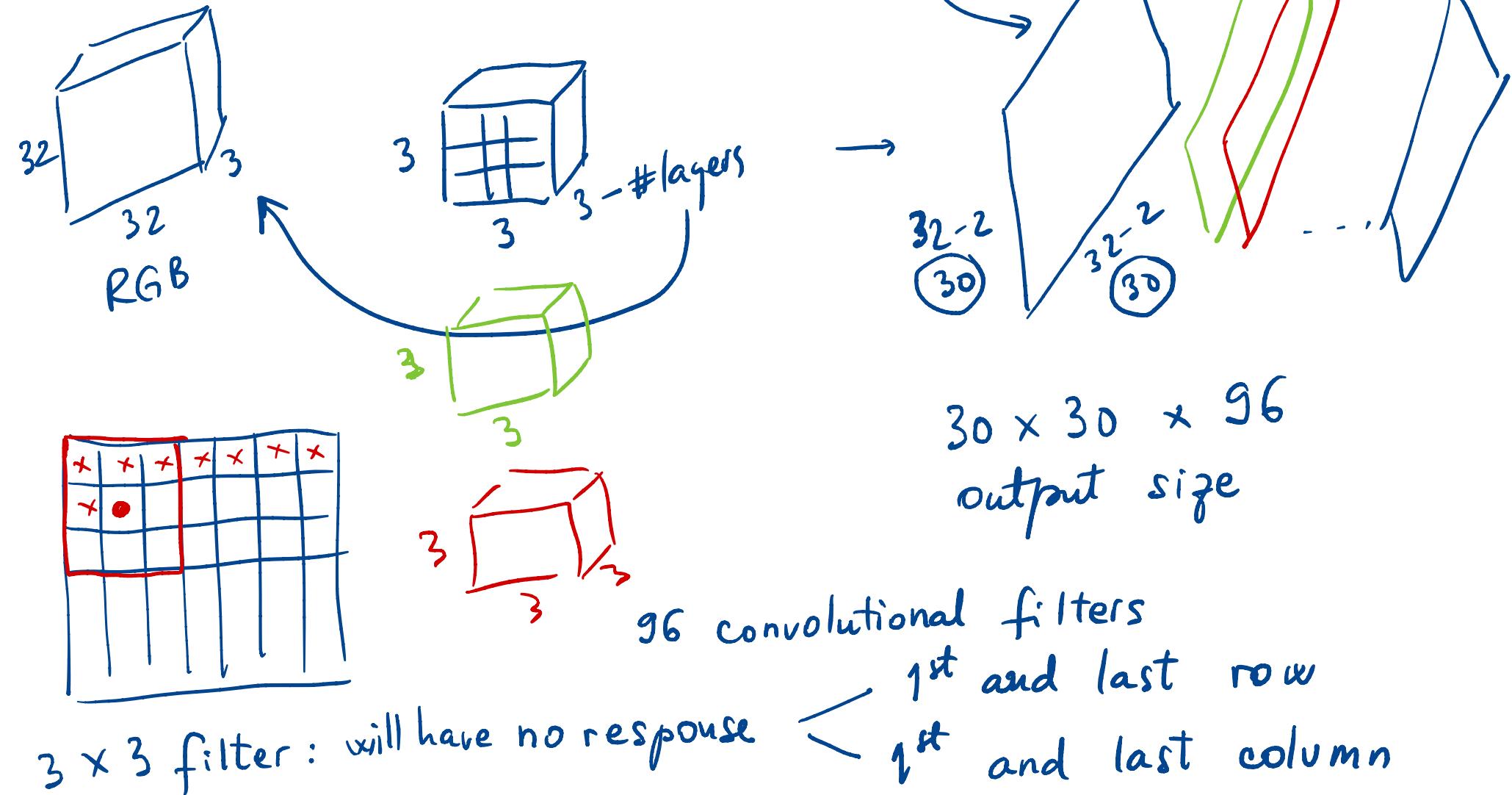


Feature extractor



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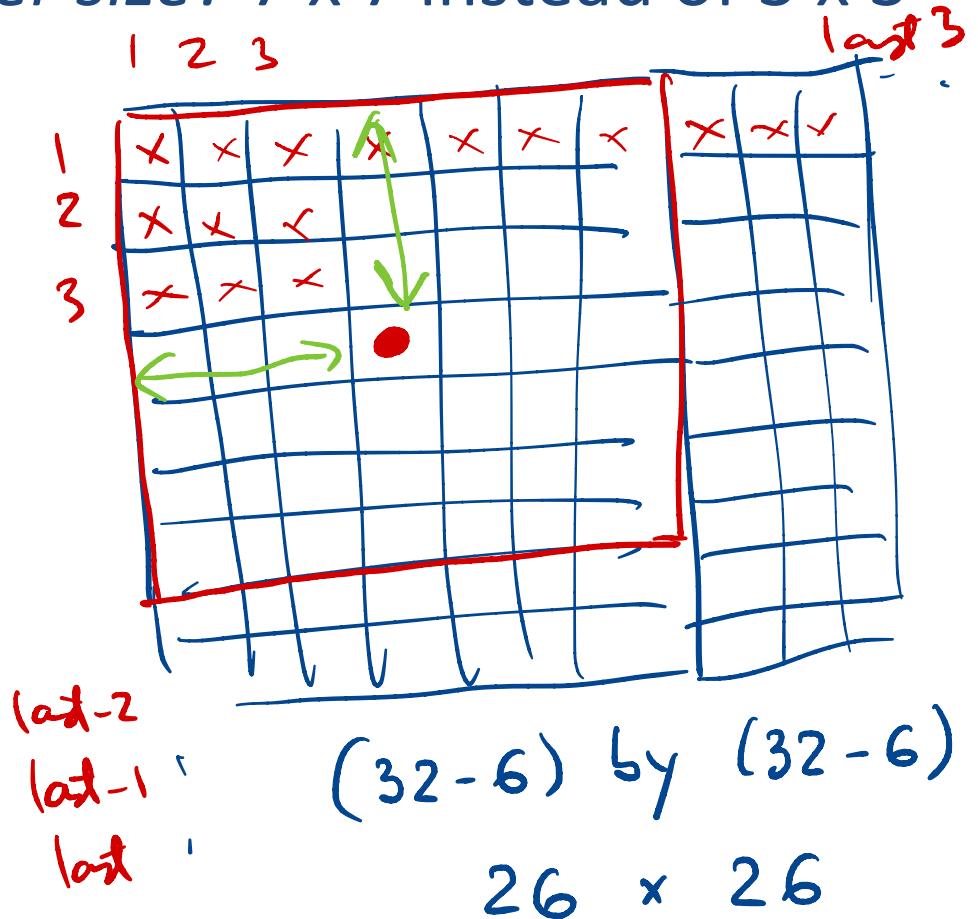
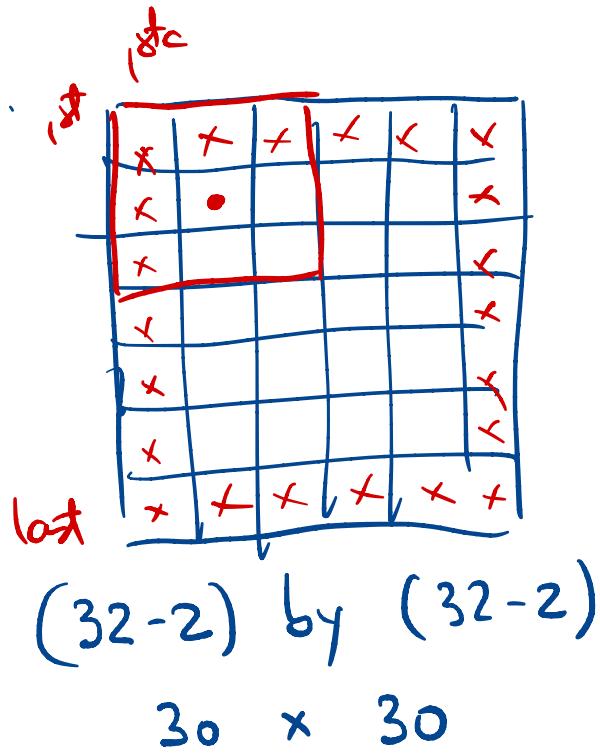
Activation Maps



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Output Size

What if we change the filter size? 7 x 7 instead of 3 x 3



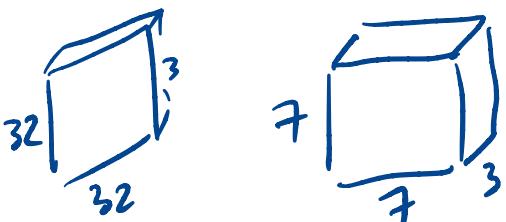
Parameters vs Hyperparameters

Learned parameters

1. Parameters: weights and bias values

* assume RGB color images

- For one 7×7 convolutional filter:

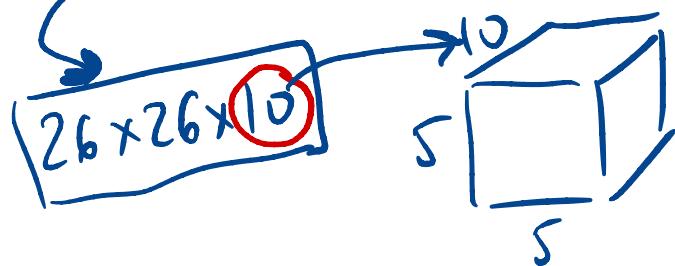

$$32 \times 32 \times 3 \text{ input} \rightarrow 7 \times 7 \times 3 \text{ filter} \rightarrow 7 \times 7 \times 3 = 49 \times 3 = 147 \text{ weights} + 1 \text{ bias} = 148 \text{ parameters}$$

- First hidden layer (a block of ten 7×7 convolutional filters):

$$148 \times 10 = 1480 \text{ parameters}$$

Output size: $26 \times 26 \times 10$

- Second hidden layer (a block of two 5×5 conv filters):


$$26 \times 26 \times 10 \text{ input} \rightarrow 5 \times 5 \times 10 \text{ filter} \rightarrow 5 \times 5 \times 10 = 250 \text{ weights} + 1 \text{ bias} = 251 \text{ parameters}$$

Total: $2 \times 251 = 502 \text{ parameters}$



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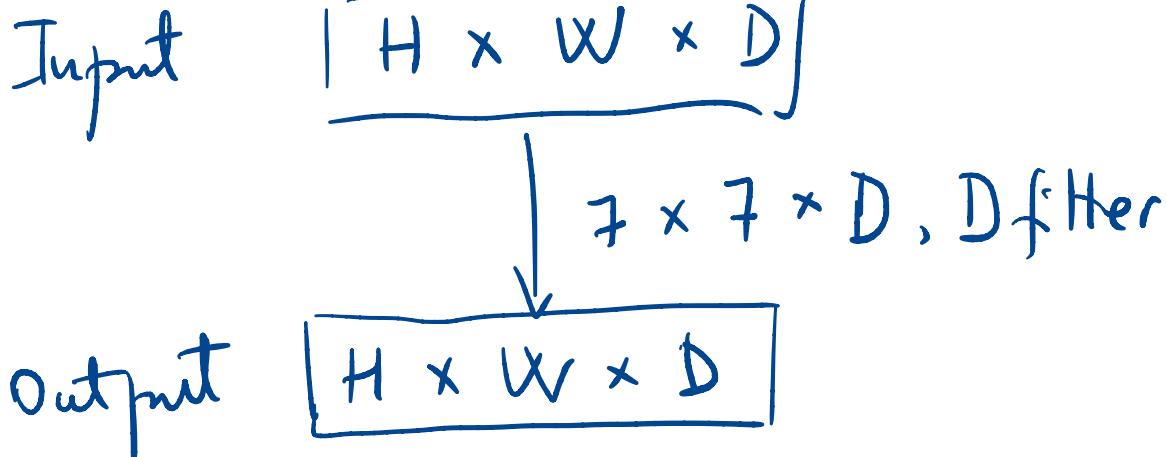
Parameters vs Hyperparameters

1. Parameters: weights and bias values
2. Hyperparameters:
 - For all NN:
 - number of hidden layers, number of neurons
 - optimizer, activation function
 - Specific to CNNs:
 - Number of filters in a convolutional block : powers of 2
 - Window size (F) - 11×11 , 7×7 , 3×3 , 1×1
 - Stride
 - Zero-padding



Window Size Comparison

1 layer of 7×7 filters



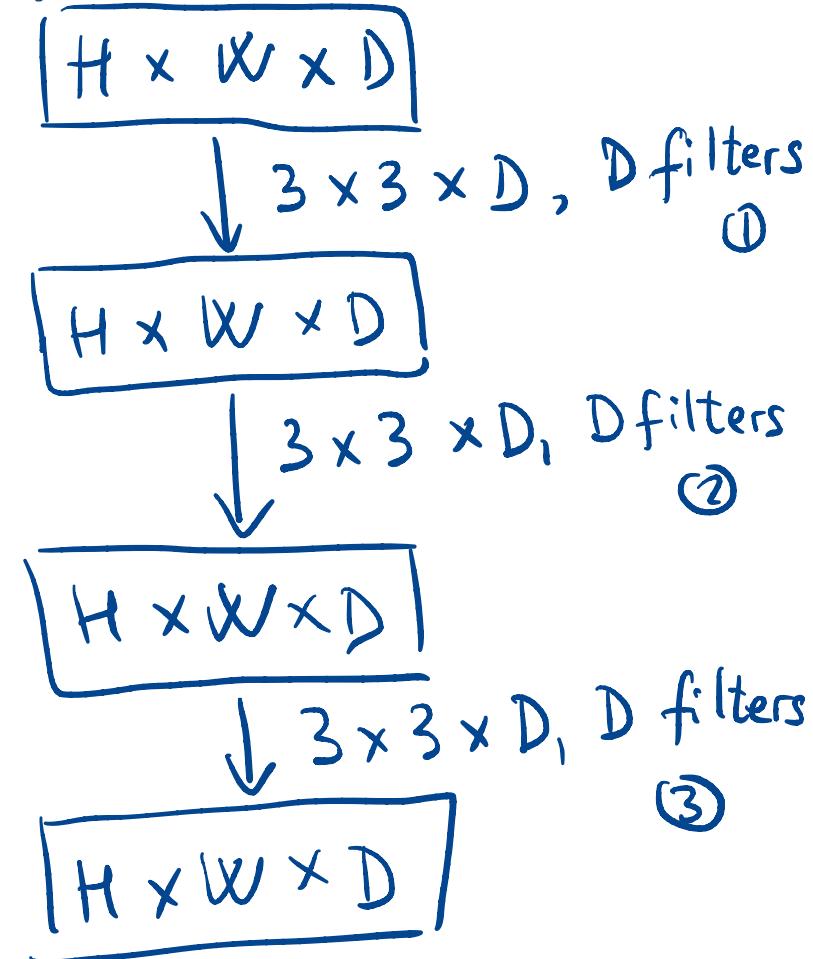
$$(7 \times 7 \times D + 1) * D = 49D^2 + D$$

$$(3 \times 3 \times D + 1) * D = 9D^2 + D$$

$$3 * (9D^2 + D) = 27D^2 + 3D$$

Almost 50%

3 layers of 3×3 filters



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Window Size Comparison

1 layer of 7 x 7 filters

3 layers of 3 x 3 filters



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