


Practice – CNN

- Run “7.1. CNN (AlexNet).ipynb”



Load pre-trained image classification models

```
[2] import torchvision  
     model = torchvision.models.alexnet(pretrained=True)
```

Downloading: "<https://download.pytorch.org/models>
100%  233M/233M

Torchvision - <https://pytorch.org/vision/stable/index.html>

ImageNet - <http://www.image-net.org/>

Image Classification - <https://machinelearningmastery.com/applications-of-deep-learning-for-computer-vision/>

Computer vision tasks

Alex Net
VGG16
Res Net

Classification



U Net

Semantic Segmentation



GRASS, CAT,
TREE, SKY

No objects, just pixels

Classification + Localization



CAT

Single Object

Faster RCNN

Object Detection



DOG, DOG, CAT

Multiple Object

Mask RCNN

Instance Segmentation

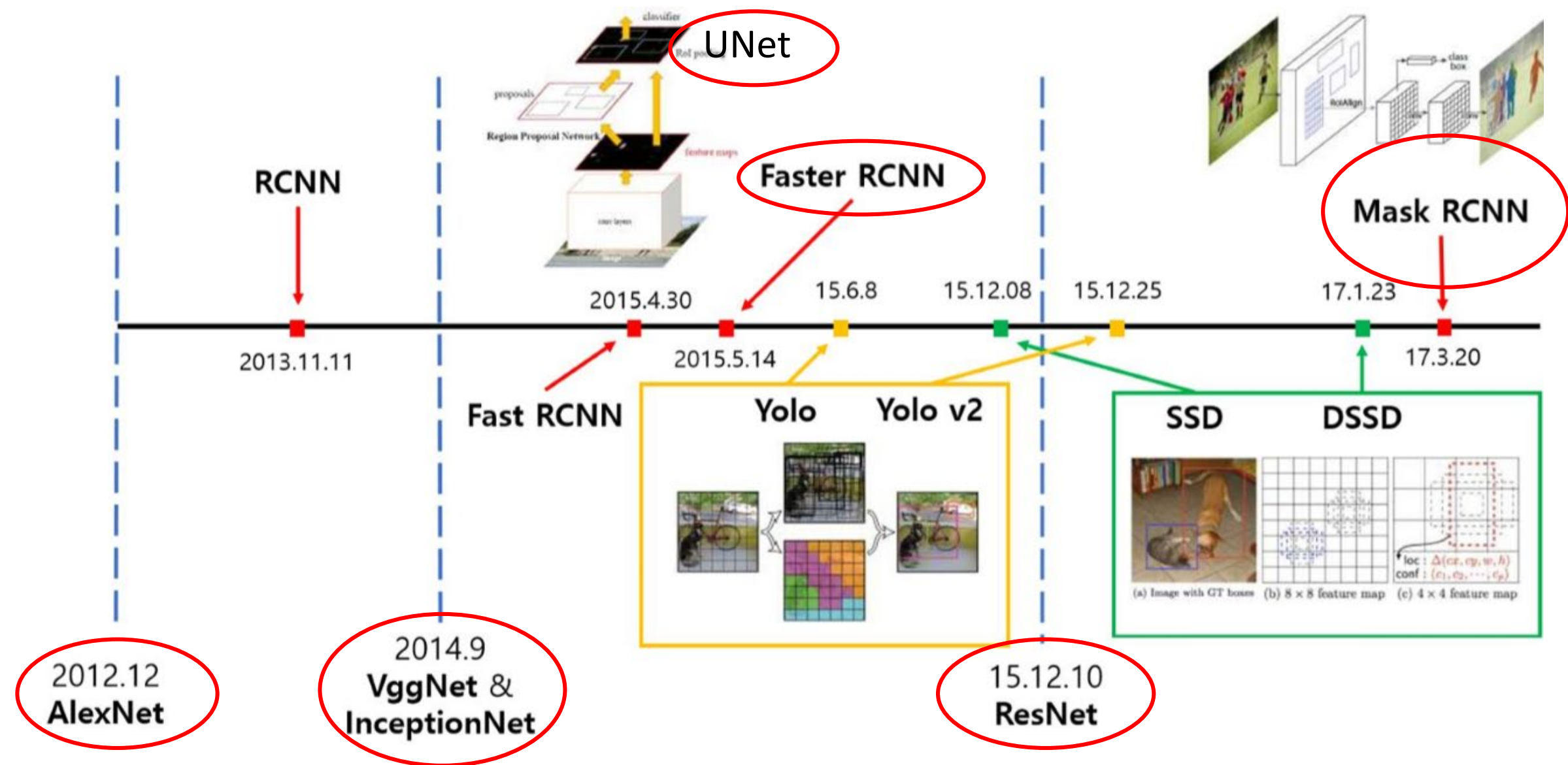


DOG, DOG, CAT

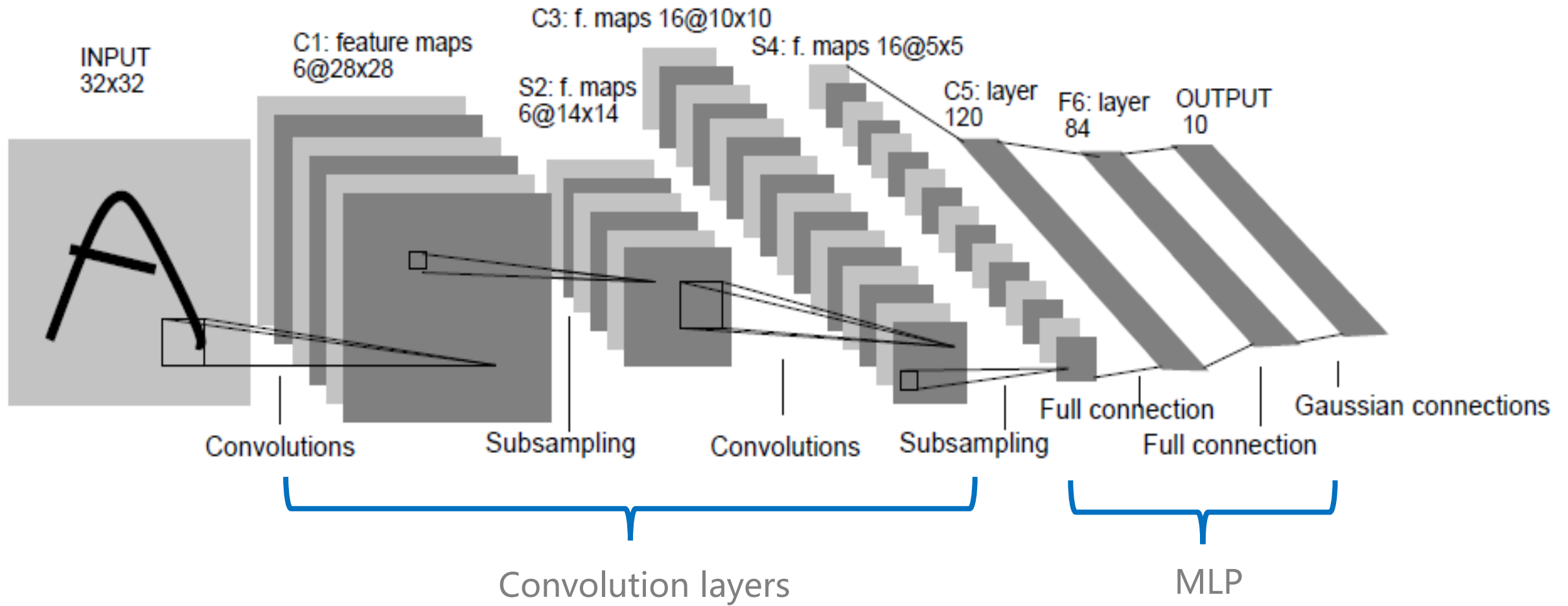
This image is CC0 public domain

圖片來源: <https://kharshit.github.io/blog/2019/08/23/quick-intro-to-instance-segmentation>

CNN family



LeNet



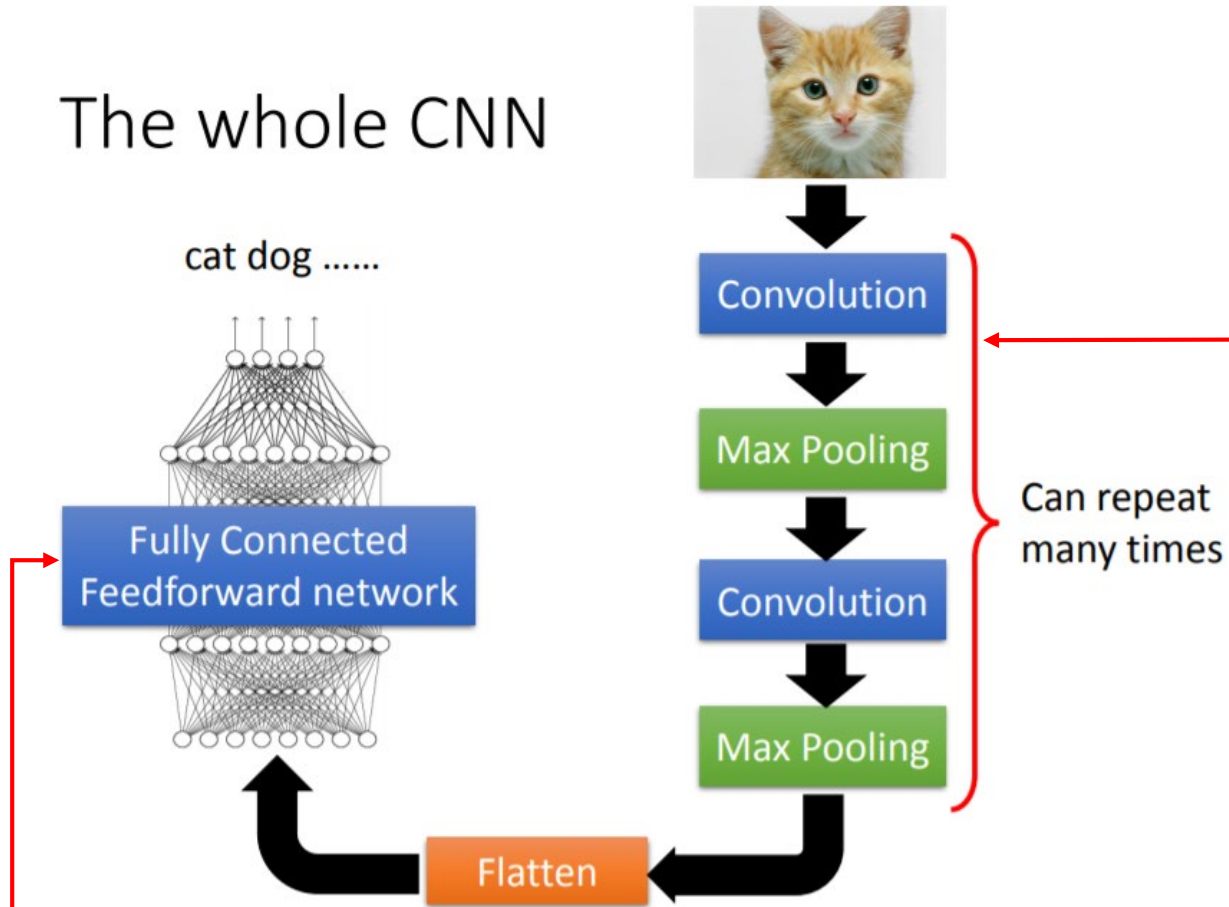
LeCun, Y., Bottou, L., Bengio, Y., & Haffner, P. (1998). Gradient-based learning applied to document recognition. Proceedings of the IEEE, 86(11), 2278-2324.

Put model in evaluation mode and in GPU

```
In [3]: model.eval()  
        model.to(device)
```


CNN contains two sections: "features" and "classifier"

The whole CNN



Reference: 李弘毅 ML Lecture 10
<https://youtu.be/FrKWiv254g>

AlexNet(

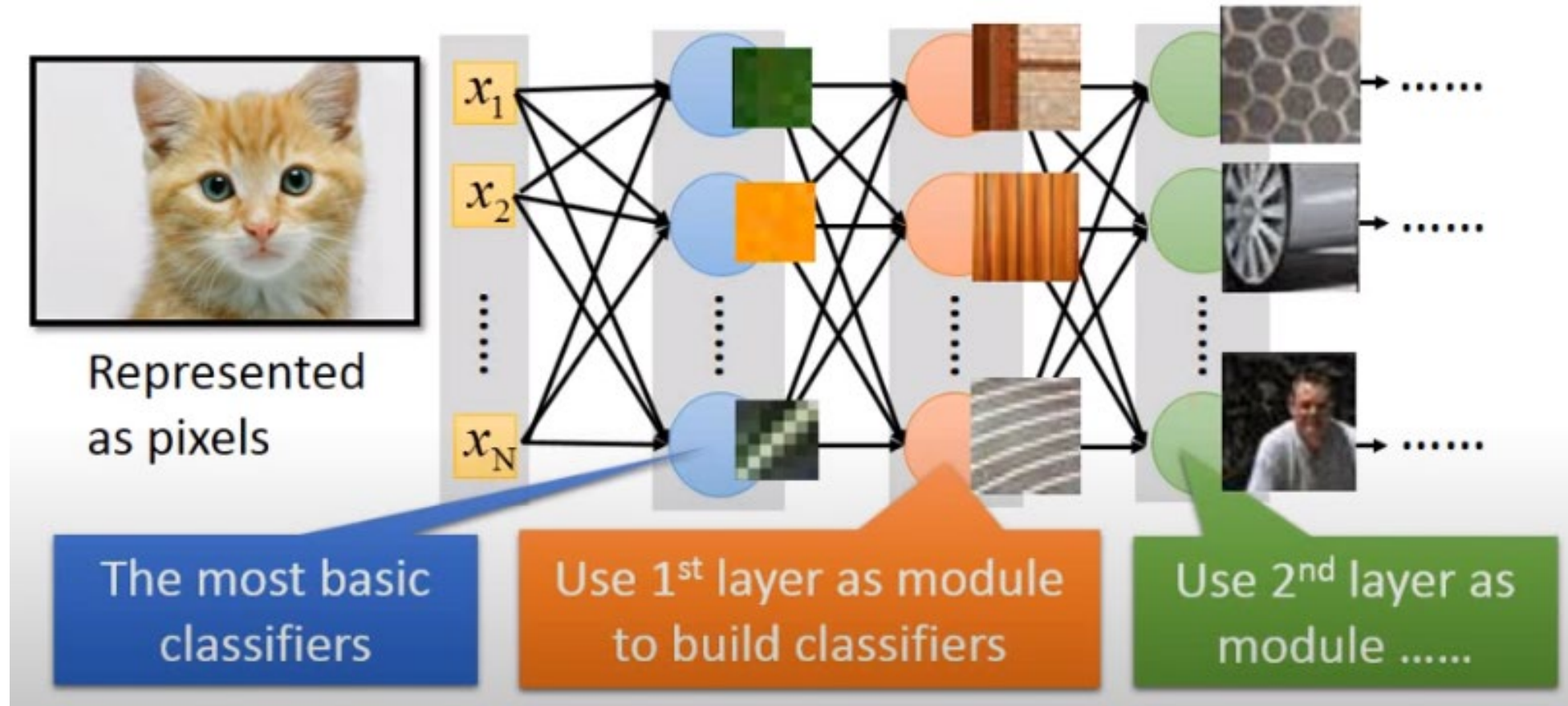
```
(features): Sequential(
  (0): Conv2d(3, 64, kernel_size=(11, 11), stride=(4, 4), padding=0)
  (1): ReLU(inplace=True)
  (2): MaxPool2d(kernel_size=3, stride=2, padding=0, dilation=1)
  (3): Conv2d(64, 192, kernel_size=(5, 5), stride=(1, 1), padding=0)
  (4): ReLU(inplace=True)
  (5): MaxPool2d(kernel_size=3, stride=2, padding=0, dilation=1)
  (6): Conv2d(192, 384, kernel_size=(3, 3), stride=(1, 1), padding=0)
  (7): ReLU(inplace=True)
  (8): Conv2d(384, 256, kernel_size=(3, 3), stride=(1, 1), padding=0)
  (9): ReLU(inplace=True)
  (10): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=0)
  (11): ReLU(inplace=True)
  (12): MaxPool2d(kernel_size=3, stride=2, padding=0, dilation=1)
)
```

```
(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=1000, bias=True)
)
```

Why not using MLP to classify images?

If we feed an image to MLP, then each neuron "sees" the whole image's pixels.



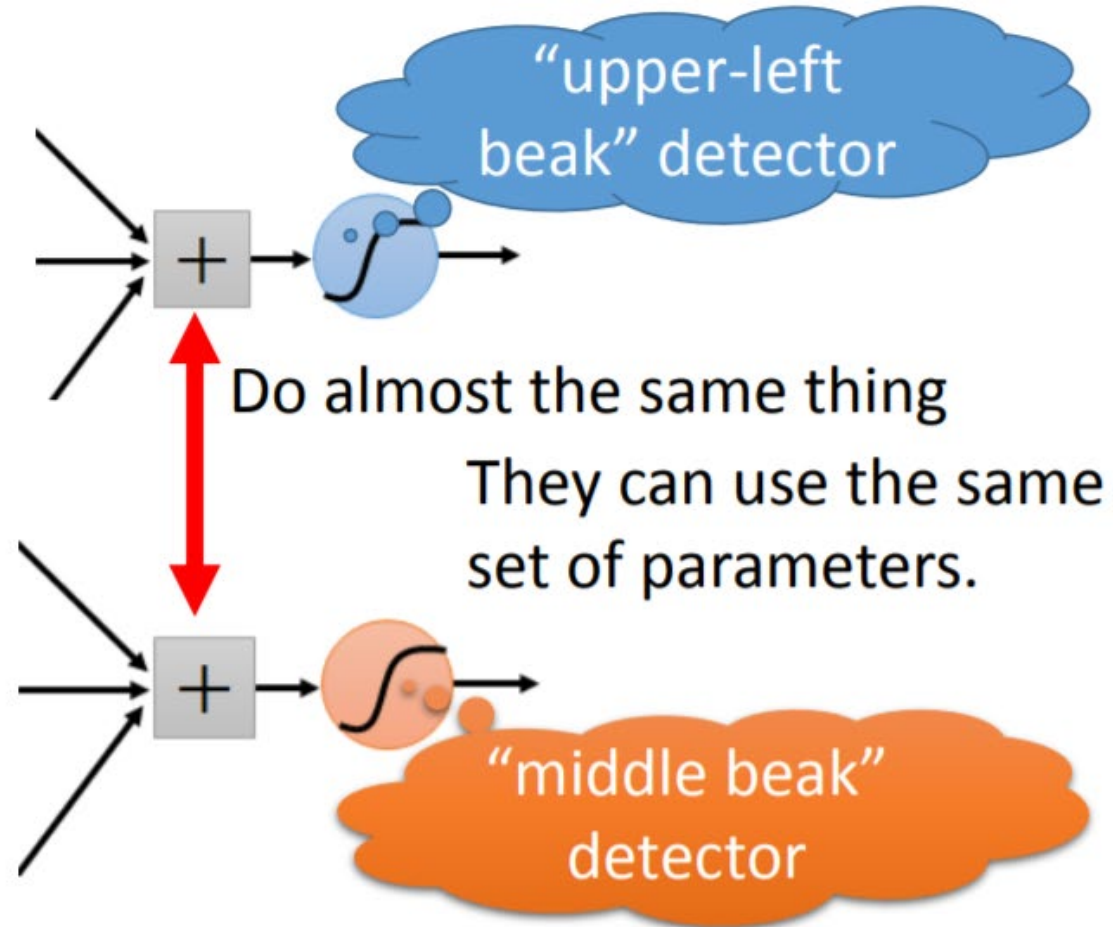
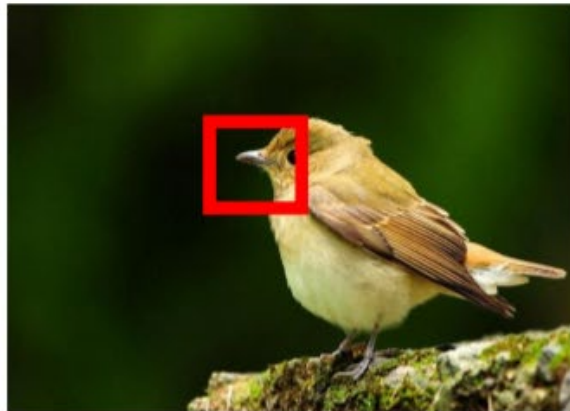
Some patterns are much smaller than the whole image

A neuron does not have to see the whole image to discover the pattern.

Connecting to small region with less parameters



The same patterns appear in different regions



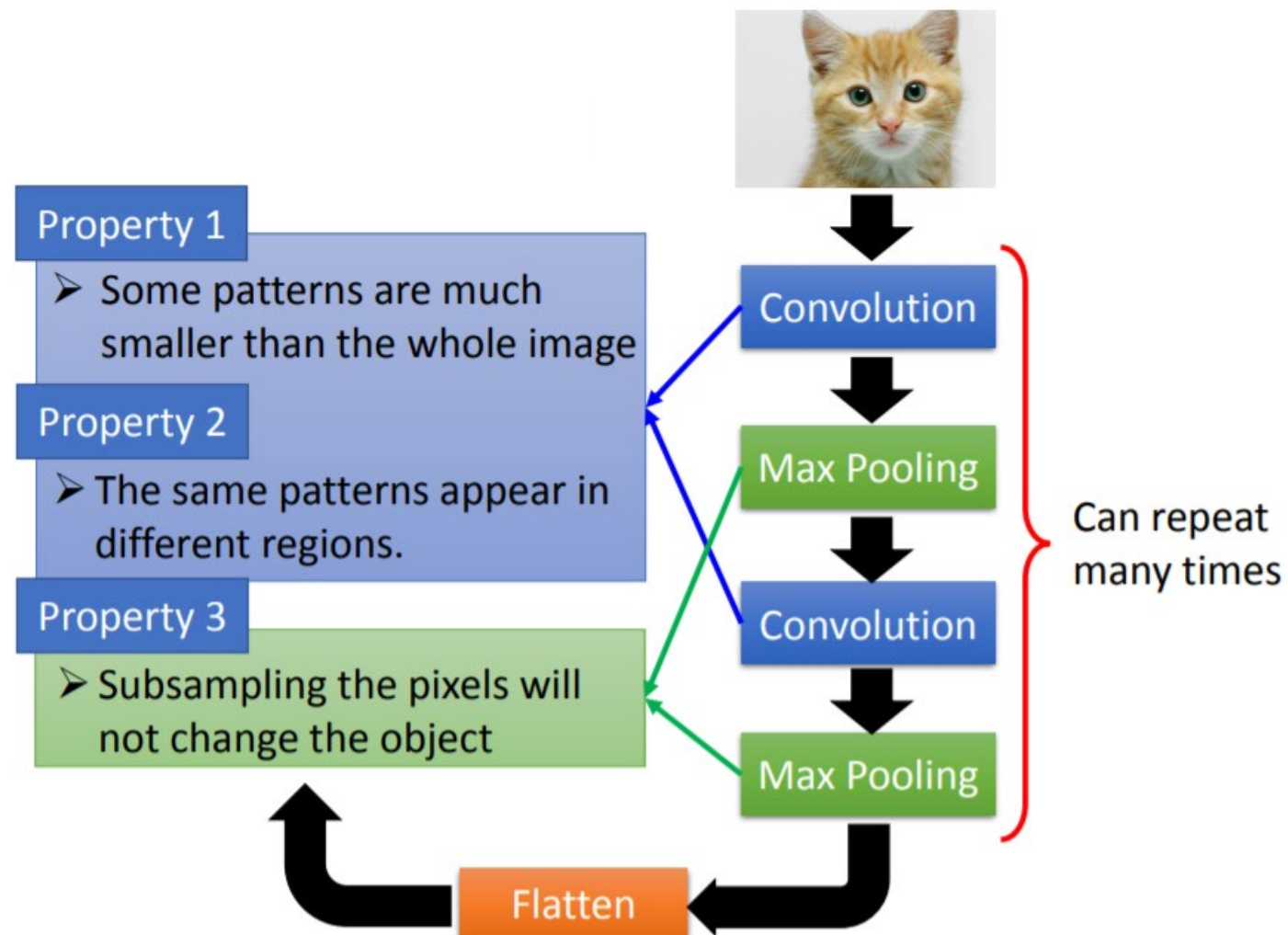
Subsampling the pixels will not change the object



We can subsample the pixels to make image smaller

➡ Less parameters for the network to process the image

Use convolution and pooling operations to extract important features from input image



The day MLP surpasses CNN and Transformer?

MLP-Mixer: An all-MLP Architecture for Vision

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keysers, usz, lucic, adosovitskiy}@google.com

[†]work done during Google AI Residency

Use CV to read image file

```
In [6]: import cv2
import matplotlib.pyplot as plt
image = cv2.imread(fname)
image = cv2.cvtColor(image,cv2.COLOR_BGR2RGB)
plt.imshow(image)
plt.show()
```

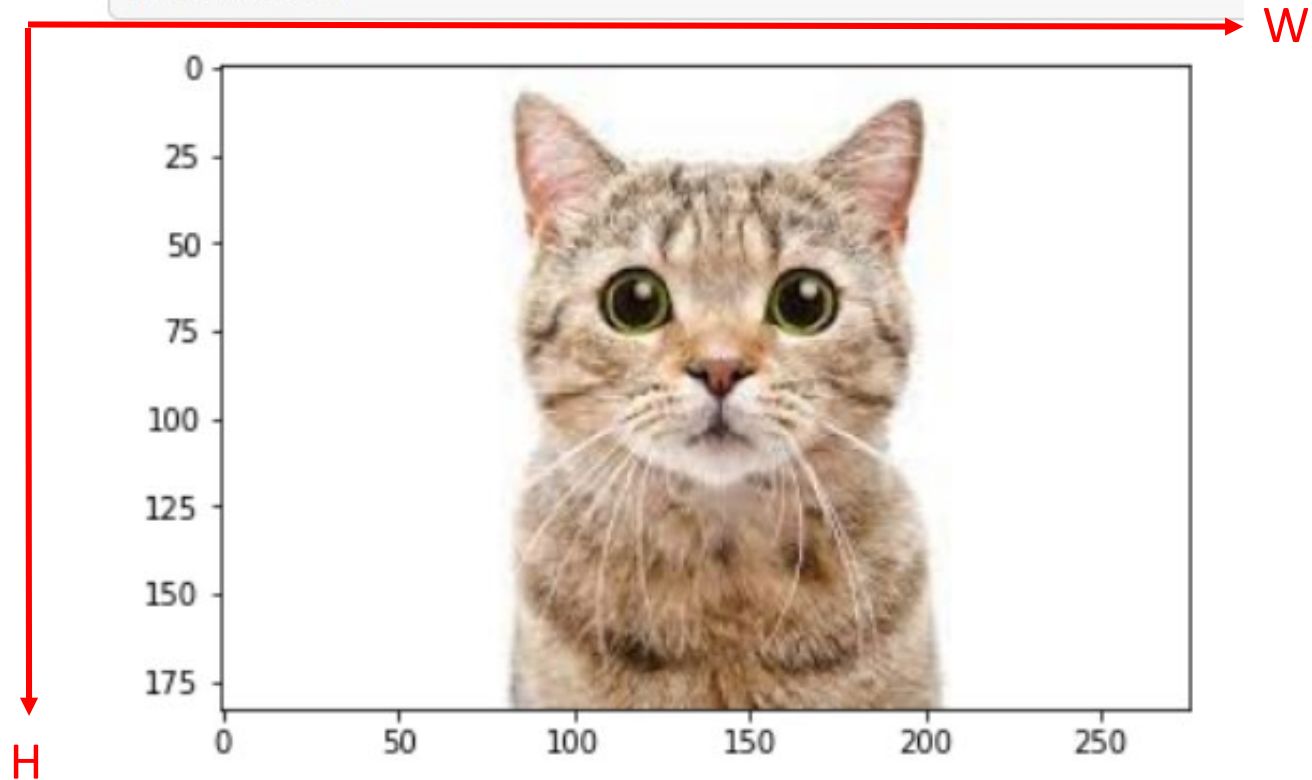


Image pre-processing

- Image width and height – resize, center crop
- Pixel values – Standardized to $[0, 1]$, normalized to $N(0, 1)$

```
In [7]: from torchvision import transforms
transformer = transforms.Compose([
    transforms.Resize(224),
    transforms.CenterCrop(224),
    transforms.ToTensor(),
    transforms.Normalize(mean=[0.5, 0.5, 0.5], std=[0.5, 0.5, 0.5] )])
```

```
In [8]: from PIL import Image
PILImg= Image.fromarray(image.astype('uint8')).convert('RGB')
PILImg = transformer(PILImg)
PILImg.shape
```

```
Out[8]: torch.Size([3, 224, 224])
```

Prepare input format

Input to CNN

```
In [9]: imageTensor = torch.unsqueeze(PILImg, 0)
        imageTensor.shape
```

```
Out[9]: torch.Size([1, 3, 224, 224])
```

Input to MLP

```
In [9]: tensorX = torch.FloatTensor(trainX).to(device)
        tensorY_hat = torch.LongTensor(trainY_hat).to(device)
        print(tensorX.shape, tensorY_hat.shape)

        torch.Size([128, 2]) torch.Size([128])
```

1st convolution

```
AlexNet(  
  (features): Sequential(  
    (0): Conv2d(3, 64, kernel_size=(11, 11), stride=(4, 4), padding=2)  
    (1): ReLU(inplace=True)  
    (2): MaxPool2d(kernel_size=3, stride=2, padding=0, dilation=1)  
    (3): Conv2d(64, 192, kernel_size=(5, 5), stride=(1, 1), padding=1)  
    (4): ReLU(inplace=True)  
    (5): MaxPool2d(kernel_size=3, stride=2, padding=0, dilation=1)  
    (6): Conv2d(192, 384, kernel_size=(3, 3), stride=(1, 1), padding=1)  
    (7): ReLU(inplace=True)  
    (8): Conv2d(384, 256, kernel_size=(3, 3), stride=(1, 1), padding=1)  
    (9): ReLU(inplace=True)  
    (10): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=1)  
    (11): ReLU(inplace=True)  
    (12): MaxPool2d(kernel_size=3, stride=2, padding=0, dilation=1)  
  )  
)
```

```
In [10]: conv1 = model.features[0]  
         print(conv1)  
         #InChannel=3(RGB),OutChannel=64, filter size=11, stride=4, padding=2  
  
         Conv2d(3, 64, kernel_size=(11, 11), stride=(4, 4), padding=(2, 2))
```

Filter searches patterns in a small region

1	0	0	0	0	1
0	1	0	0	1	0
0	0	1	1	0	0
1	0	0	0	1	0
0	1	0	0	1	0
0	0	1	0	1	0

6 x 6 image

Those are the network parameters to be learned.

1	-1	-1
-1	1	-1
-1	-1	1

Filter 1
Matrix

-1	1	-1
-1	1	-1
-1	1	-1

Filter 2
Matrix

⋮

Property 1 Each filter detects a small pattern (3 x 3).

Property 1

- Some patterns are much smaller than the whole image

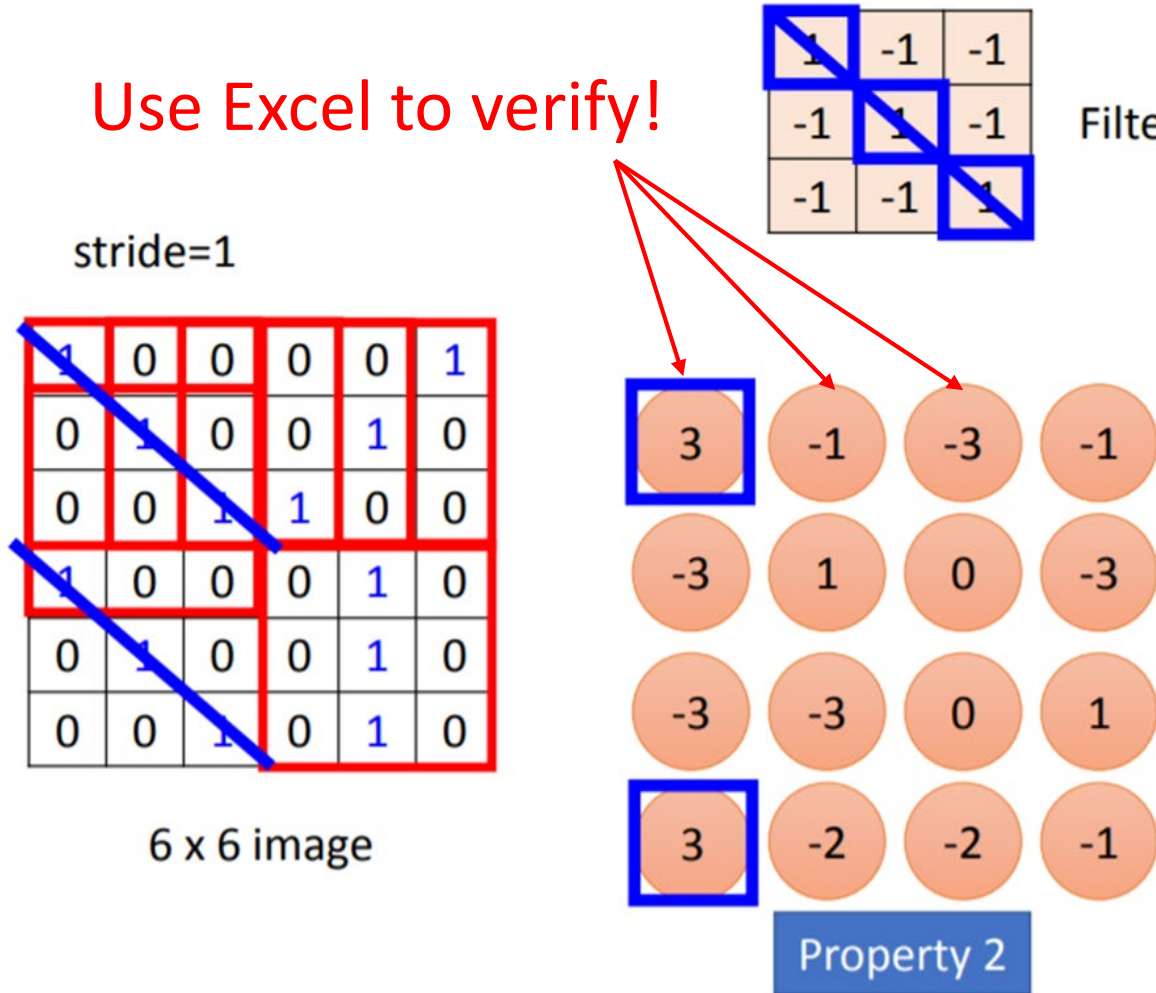
A neuron does not have to see the whole image to discover the pattern.

Connecting to small region with less parameters



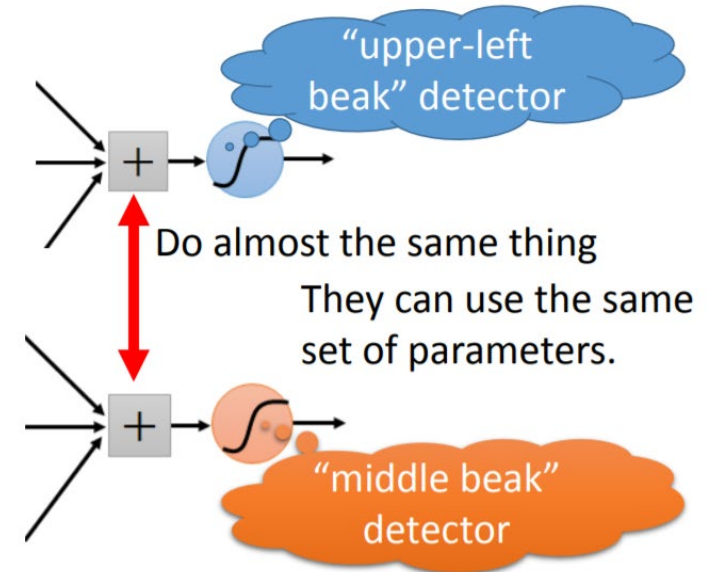
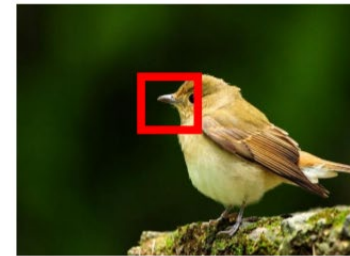
Filter searches a particular pattern in different regions

Use Excel to verify!

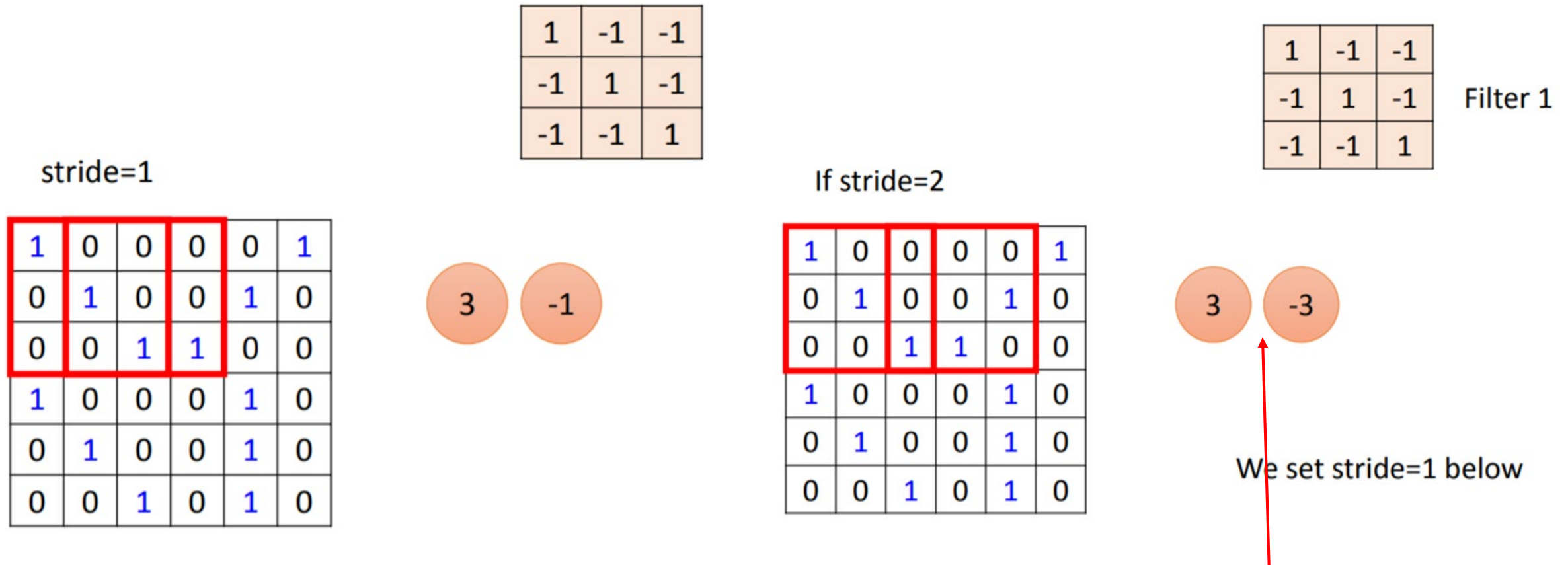


Property 2

- The same patterns appear in different regions.

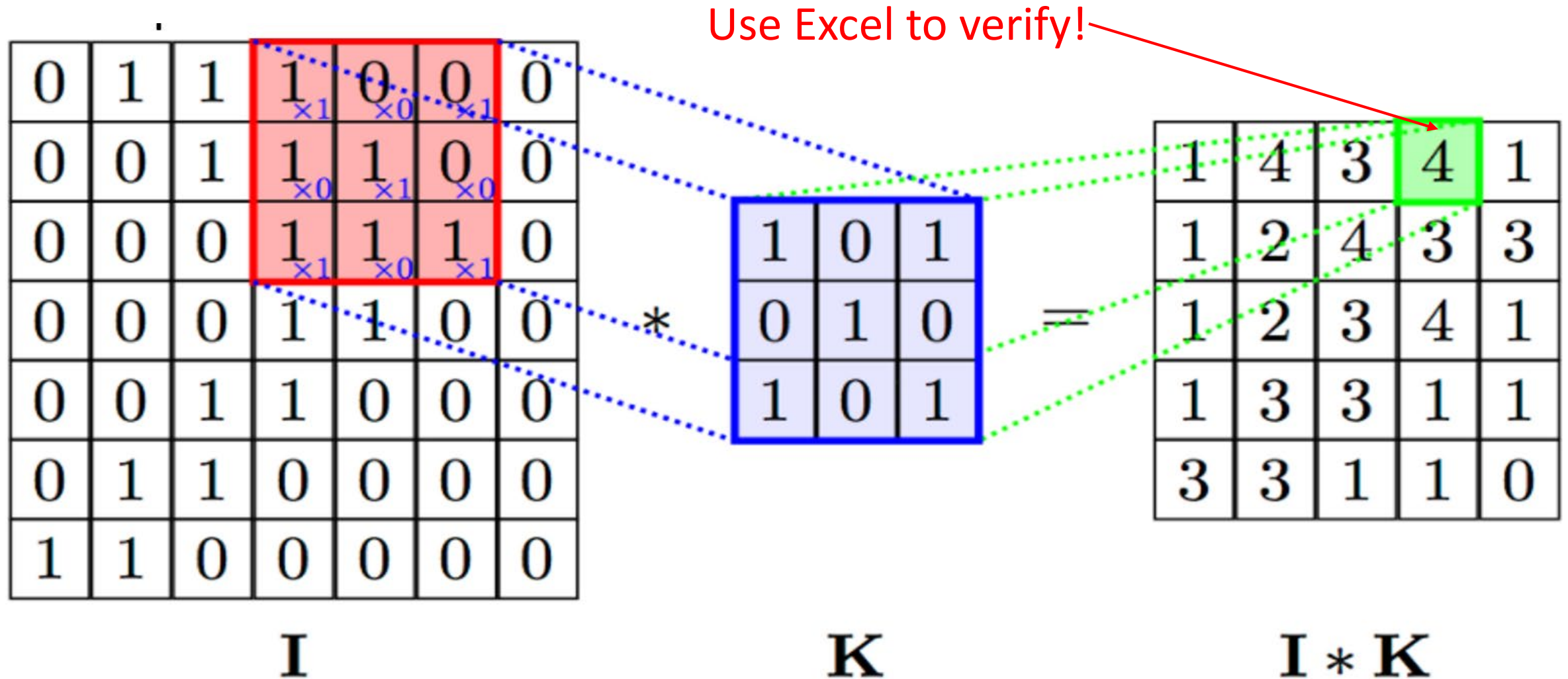


Stride determines how filter shifts



Use Excel to verify!

Filter searches a particular pattern in different regions



Visualization of a convolution operation. I is the input to the network, k represents the vector and $i*k$ represents the matrix multiplication resulting of sliding the kernel through the input. Reference (Veličković, 2016)

Filter searches a particular pattern in different regions

INPUT

FILTER

CONVOLVED FEATURE

1	1	1	0	0
0	1	1	1	0
0	0	1	1	1
0	0	1	1	0
0	1	1	0	0

1	0	1
0	1	0
1	0	1

4		

1	1	1	0	0
0	1	1	1	0
0	0	1	1	1
0	0	1	1	0
0	1	1	0	0

1	0	1
0	1	0
1	0	1

4		
2		

1	1	1	0	0
0	1	1	1	0
0	0	1	1	1
0	0	1	1	0
0	1	1	0	0

1	0	1
0	1	0
1	0	1

4	3	
2		

Use Excel to verify!

1	1	1	0	0
0	1	1	1	0
0	0	1	1	1
0	0	1	1	0
0	1	1	0	0

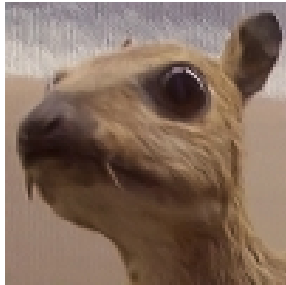
1	0	1
0	1	0
1	0	1


4	3	4
2	4	3
2	3	4

Input image

Convolution Kernel

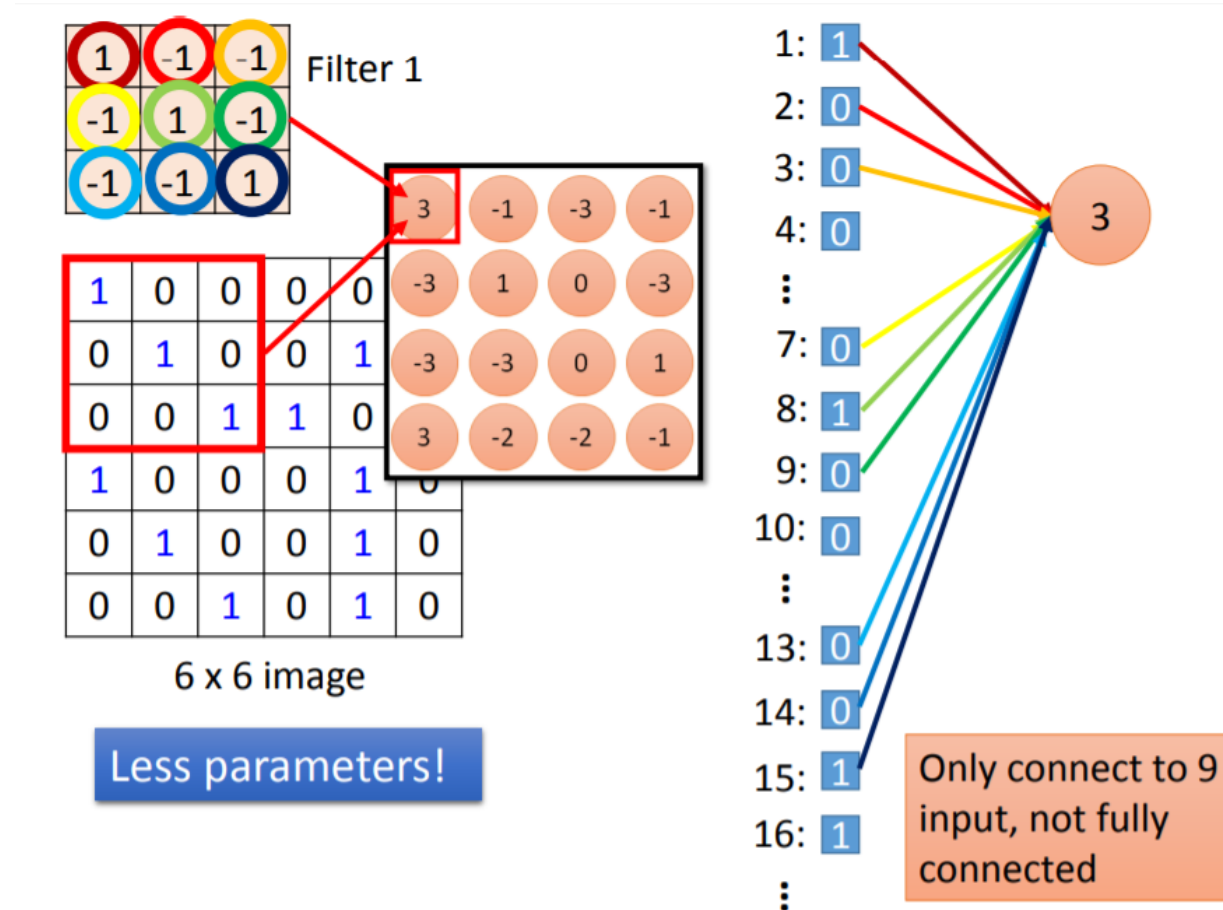
Feature map



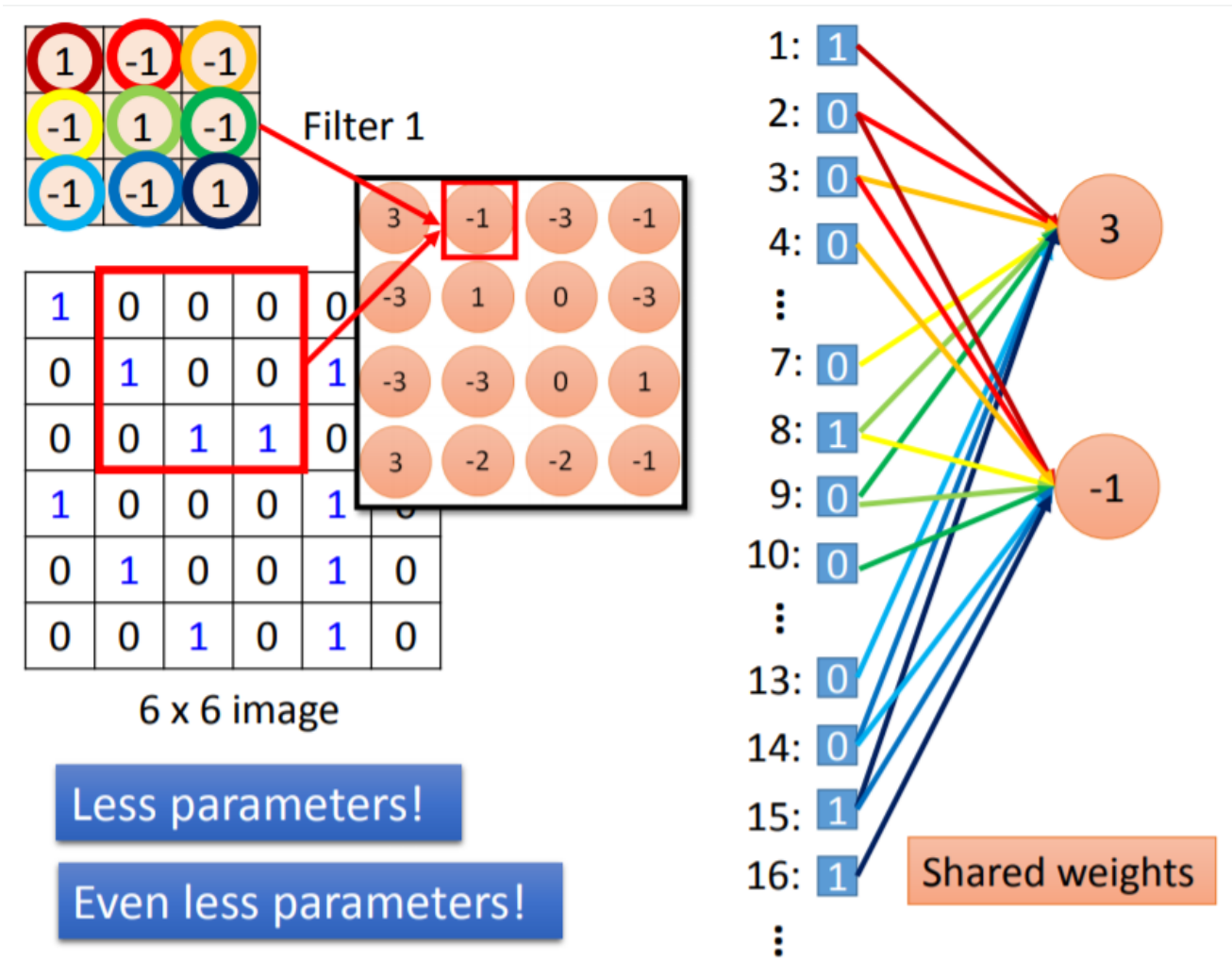
$$\begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}$$


圖來源: <https://developer.nvidia.com/discover/convolution>

Convolution can be represented as partially connected NN, which has less parameters and is less complicated than the fully connected NN.

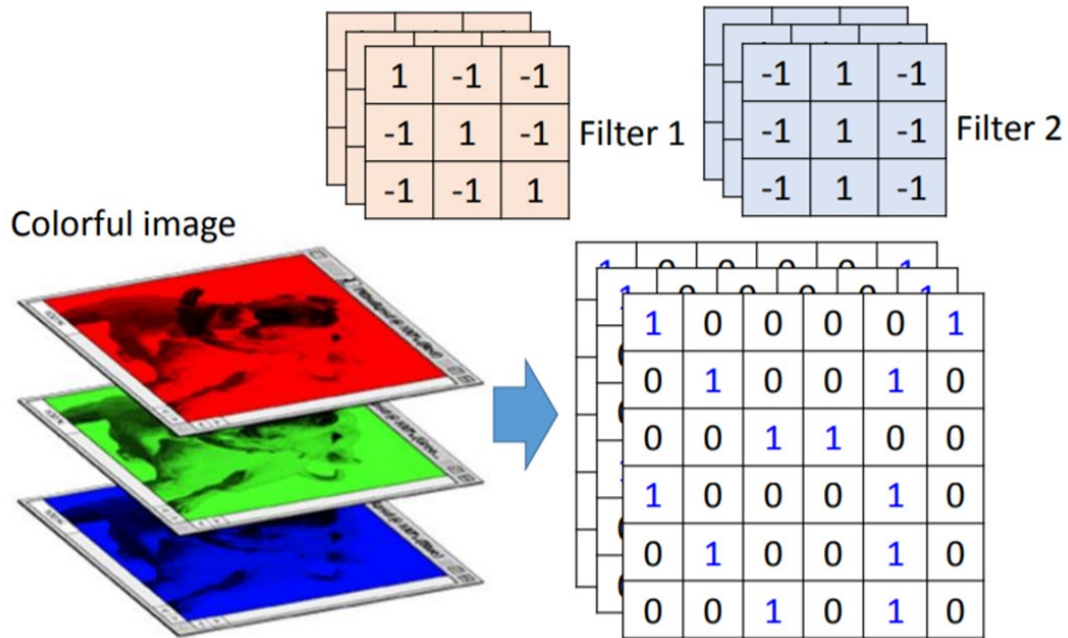


Partially connected NN with shared weights and hence with even less parameters.



Filter has depth

If input image has 3 channels, then each convolution filter also has 3 channels



```
[10] conv1 = model.features[0]
      print(conv1)
      #InChannel=3(RGB), OutChannel=64, filter size=11,

      Conv2d(3, 64, kernel_size=(11, 11), stride=(4, 4),
```

```
[11] weight1 = conv1.weight.data.cpu().numpy()
      print(weight1.shape)
      #64 filters, depth=3, size =11 by 11

      (64, 3, 11, 11)
```

Take a look at the learned filter weights of 1st convolution

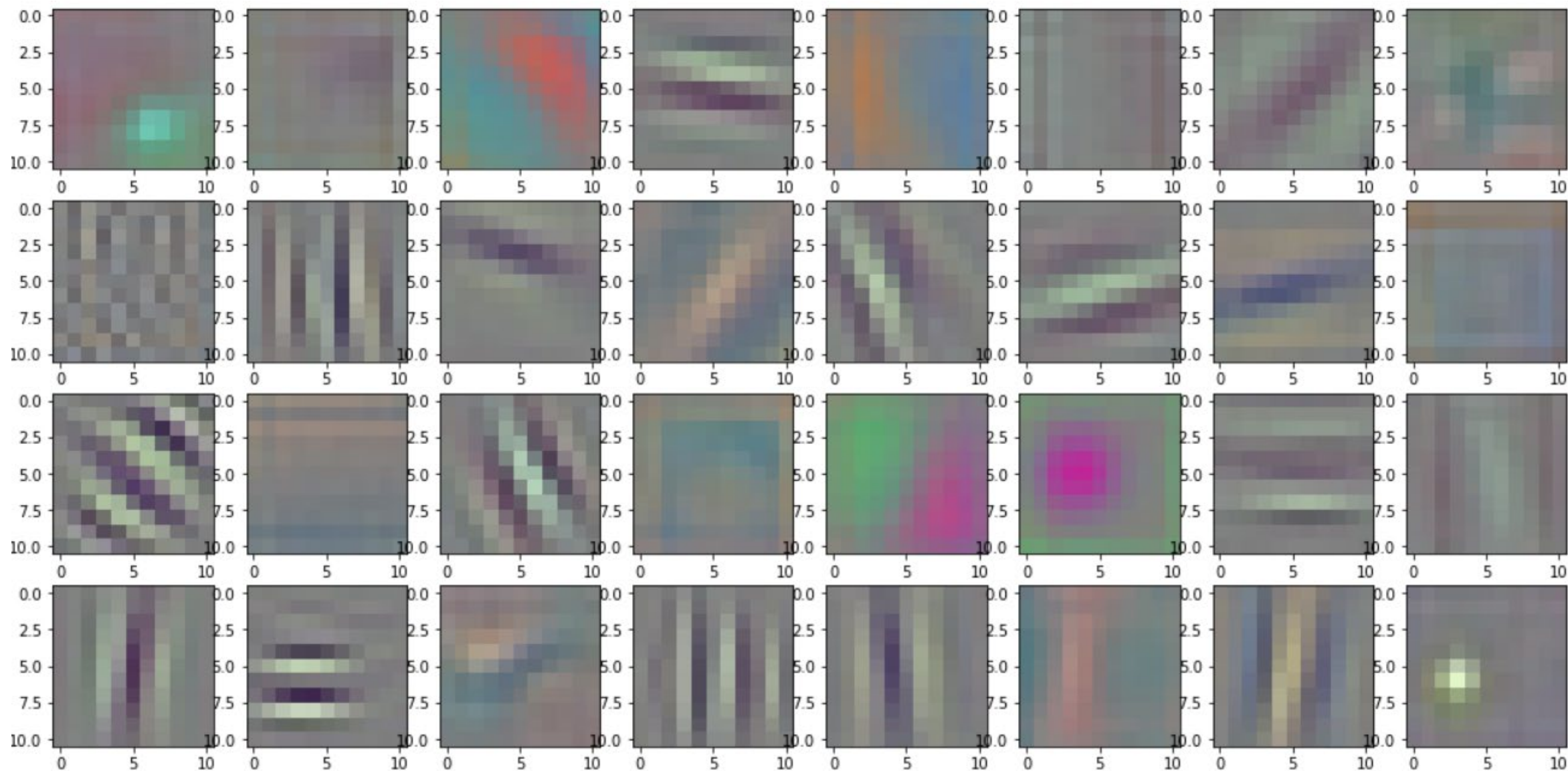
```
[11] weight1 = conv1.weight.data.cpu().numpy()
      print(weight1.shape)
      #64 filters, depth=3, size =11 by 11

      (64, 3, 11, 11)
```


Visualize filters in the 1st convolution layer

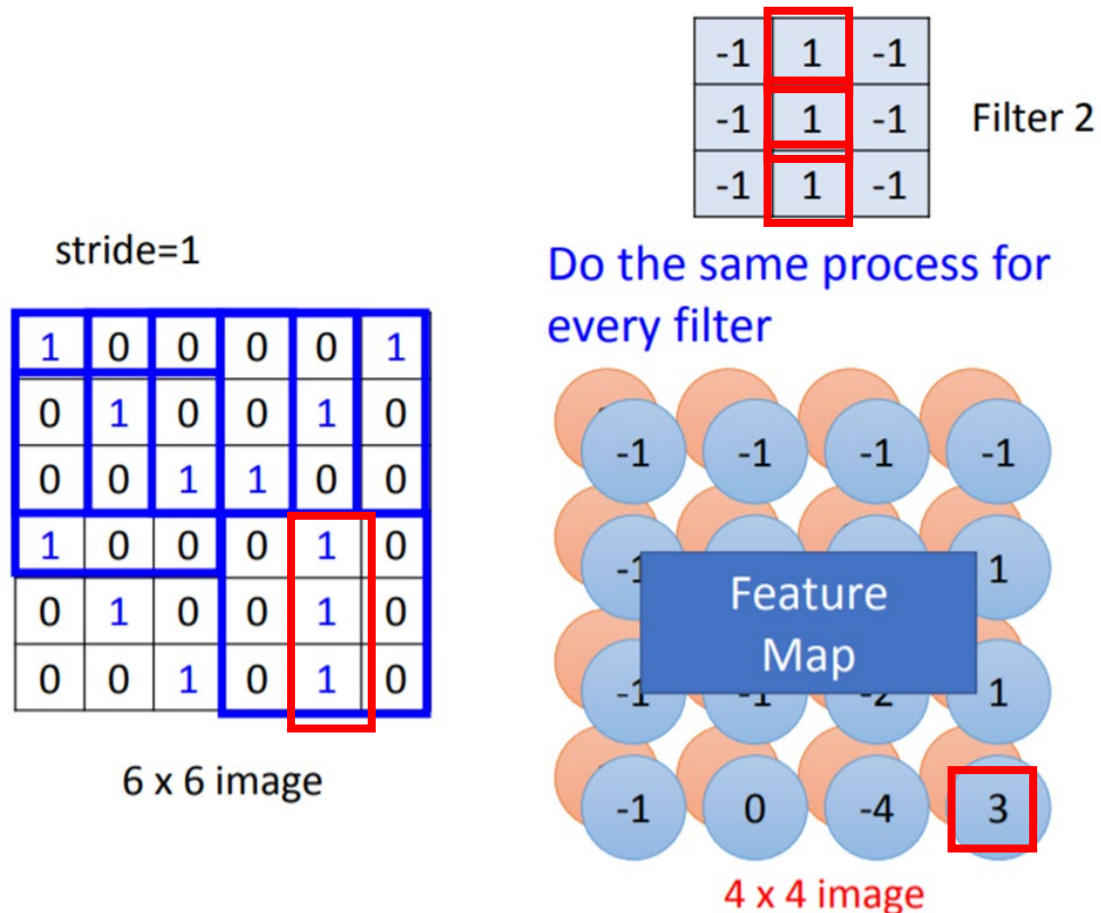
```
[13] # Visualize the first 32 of the filter weights
import numpy as np
fig=plt.figure(figsize=(18, 9))
for i in range(32):
    fig.add_subplot(4, 8, i+1)
    w = weight1[i]
    ImgArray = np.zeros((w.shape[1], w.shape[2], 3))
    ImgArray[:, :, 0] = w[0, :, :]
    ImgArray[:, :, 1] = w[1, :, :]
    ImgArray[:, :, 2] = w[2, :, :]
    ImgArray = ImgArray*0.5+0.5 # convert [-1, 1] to [0, 1]
    plt.imshow(ImgArray)
plt.show()
```

The learned filter's weights



Feature maps

Each filter searches a small region and summarizes how the specified pattern appears in different regions in a feature map



```
In [10]: conv1 = model.features[0]
print(conv1)
#InChannel=3(RGB), OutChannel=64, filter size
Conv2d(3, 64, kernel_size=(11, 11), stride=(
```

```
In [11]: weight1 = conv1.weight.data.cpu().numpy()
print(weight1.shape)
#64 filters, depth=3, size =11 by 11
(64, 3, 11, 11)
```

```
In [12]: conv1_out = conv1(imageTensor.to(device))
conv1_out.shape
#output image (feature map) has 64 channels
```

```
Out[12]: torch.Size([1, 64, 55, 55])
```

Feature map's width and height

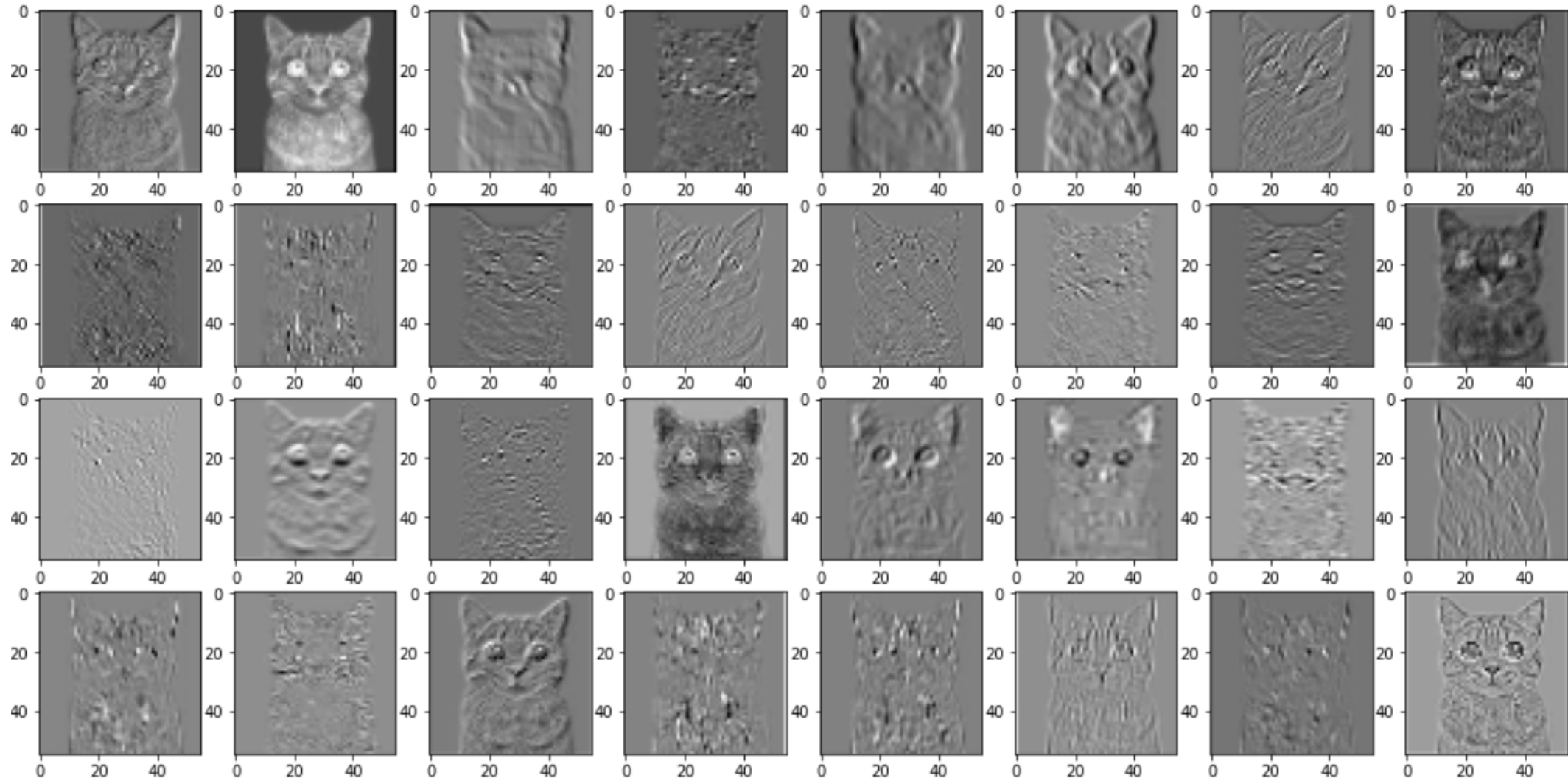
```
In [12]: conv1_out = conv1(imageTensor.to(device))  
conv1_out.shape  
#output image (feature map) has 64 channels
```

```
Out[12]: torch.Size([1, 64, 55, 55])
```

$$\frac{224 + 2 \times 2 - 11}{4} + 1 = 55.25$$

$$H_{out} = \frac{H_{in} + 2 \times padding - kernel\ size}{Stride} + 1$$

First 32 channels of the output feature map, shape = 55x55x64



Max pooling

1	-1	-1
-1	1	-1
-1	-1	1

Filter 1

-1	1	-1
-1	1	-1
-1	1	-1

Filter 2

1	-1	-1
-1	1	-1
-1	-1	1

Filter 1

-1	1	-1
-1	1	-1
-1	1	-1

Filter 2

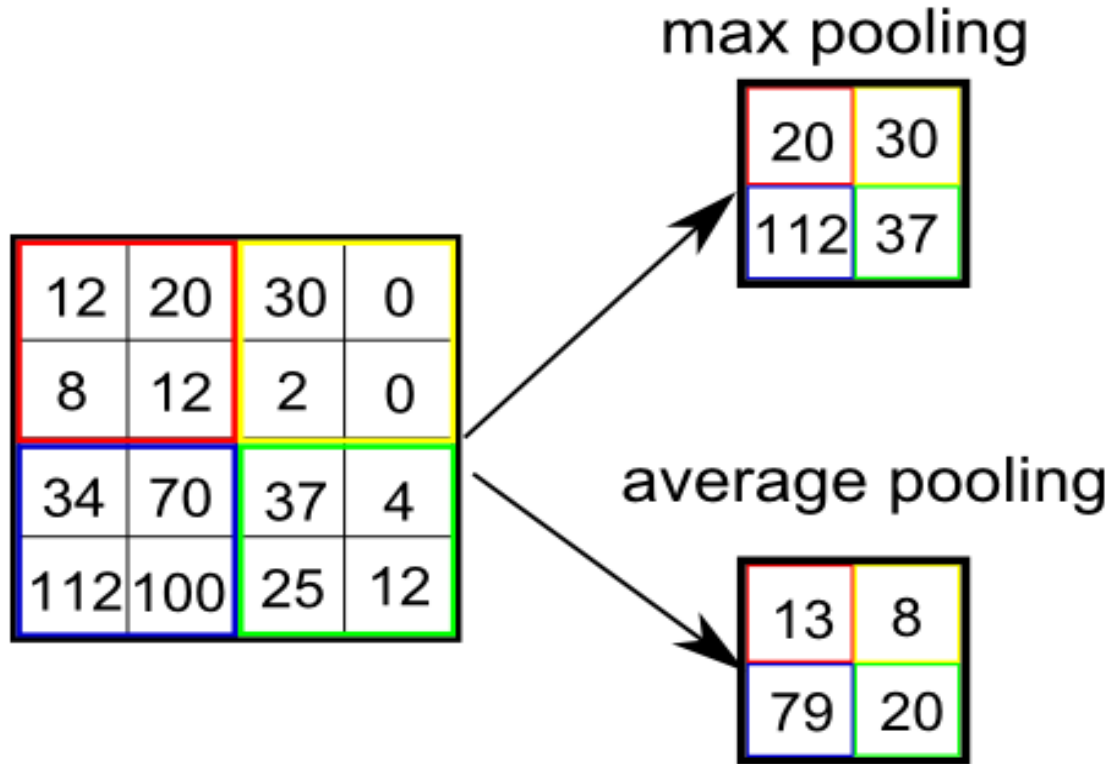
3	-1	-3	-1
-3	1	0	-3
-3	-3	0	1
3	-2	-2	-1

-1	-1	-1	-1
-1	-1	-2	1
-1	-1	-2	1
-1	0	-4	3

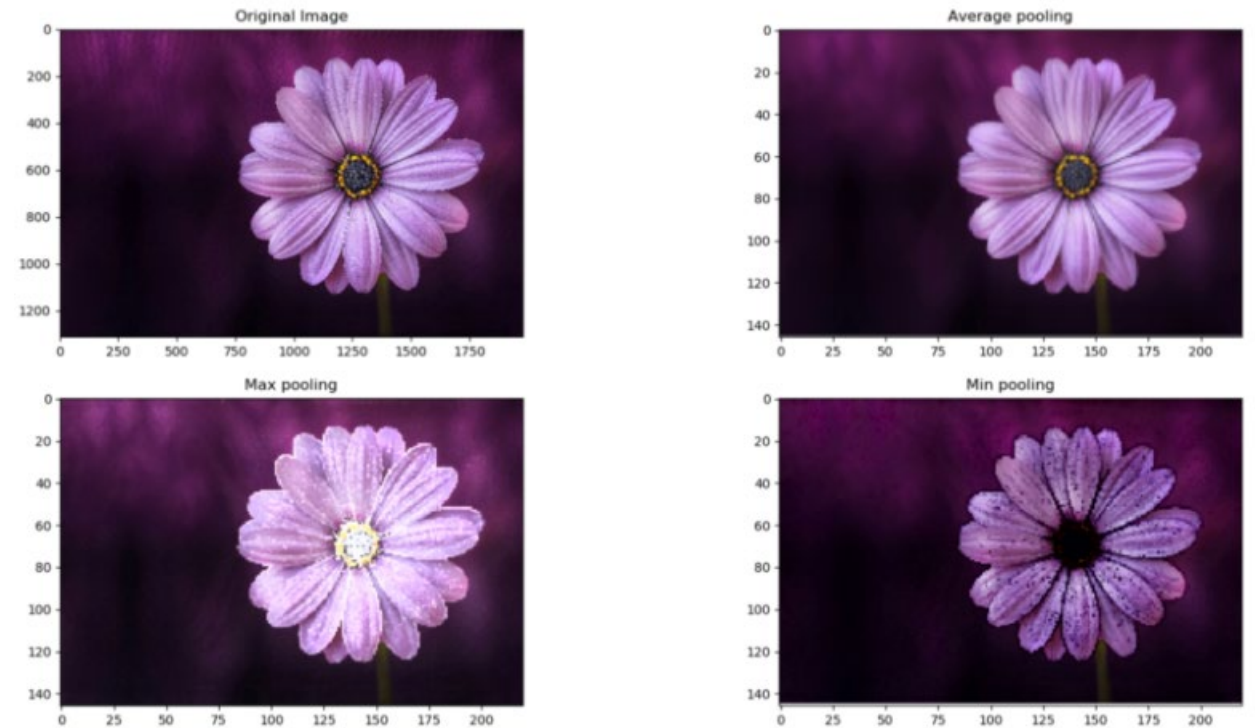
3	
	0
3	
	1

-1	
	1
	0
	3

Max pooling



(Singhal, 2017)



圖來源: <https://medium.com/@bdhuma/which-pooling-method-is-better-maxpooling-vs-minpooling-vs-average-pooling-95fb03f45a9>

Apply max pooling to the feature map from 1st convolution

features[1, 2]

```
[14]: conv1_pooling = model.features[1:3]
conv1_out1 = conv1_pooling(conv1_out)
print(conv1_out1.shape)
imgArray=conv1_out1[0].data.cpu().numpy()
fig=plt.figure(figsize=(18, 9))
for i in range(32): #visualize the first 32 channels
    fig.add_subplot(4, 8, i+1)
    plt.imshow(imgArray[i], cmap='gray')
plt.show()
```

torch.Size([1, 64, 27, 27])

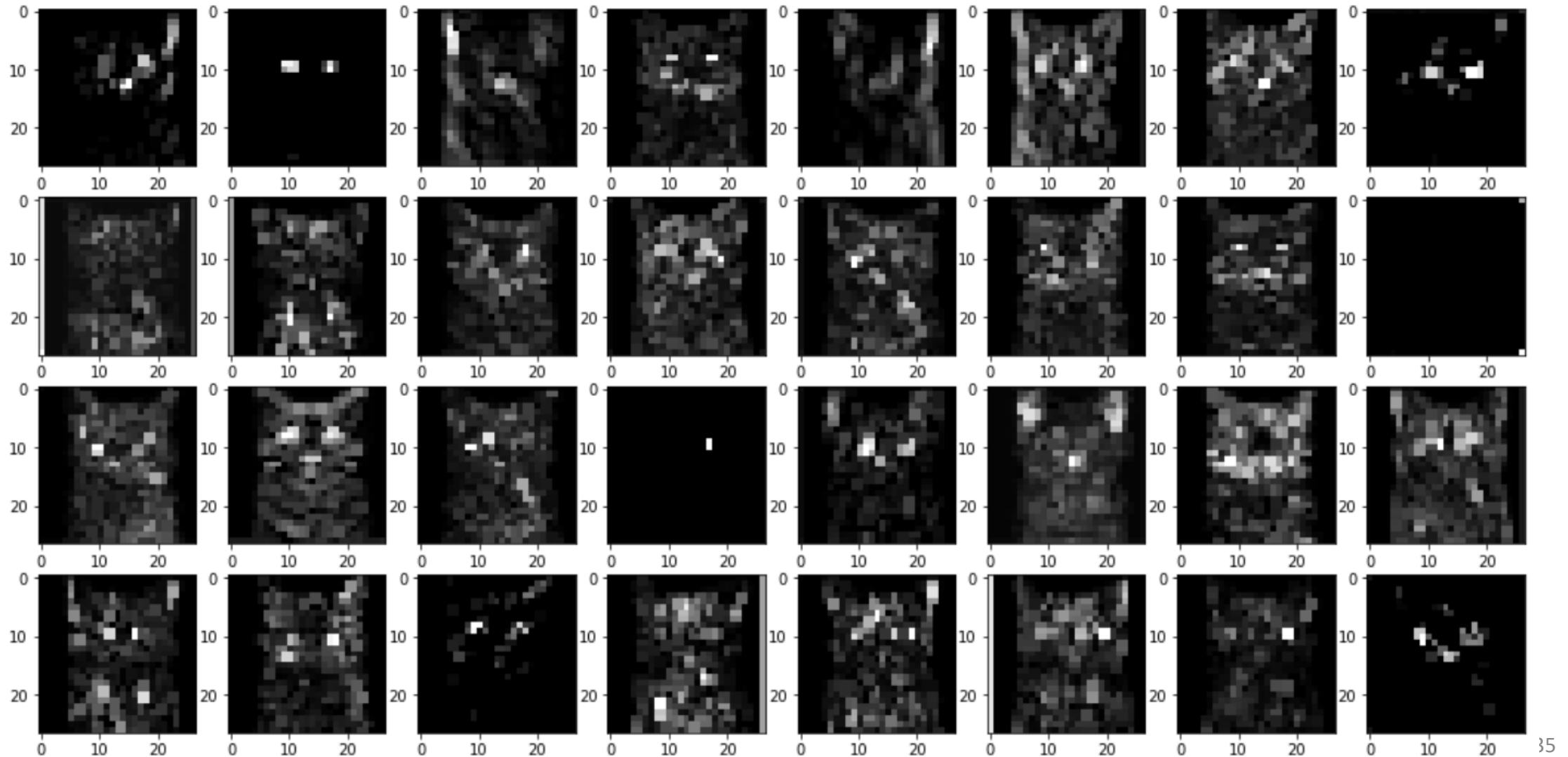
$$\frac{55 + 2 \times 2 - 3}{2} + 1 = 27$$

$$H_{out} = \frac{H_{in} + 2 \times padding - kernel\ size}{Stride} + 1$$

```
AlexNet(
  (features): Sequential(
    (0): Conv2d(3, 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)
    (3): Conv2d(64, 128, 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)
    (6): Conv2d(128, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (7): ReLU(inplace=True)
    (8): Conv2d(256, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (9): ReLU(inplace=True)
    (10): Conv2d(512, 512, 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)
  )
)
```



First 32 channels of the output feature map from max pooling,
shape = 27x27x64



2nd convolution

```
[15]: conv2 = model.features[3]
conv2_out = conv2(conv1_out1)
print(conv2_out.shape)
imgArray=conv2_out[0].data.cpu().numpy()
fig=plt.figure(figsize=(18, 9))
for i in range(32): #visualize the first 32 channels
    fig.add_subplot(4, 8, i+1)
    plt.imshow(imgArray[i], cmap='gray')
plt.show()

torch.Size([1, 192, 27, 27])
```

After convolution, the output feature map has 192 channels

$$\frac{27 + 2 \times 2 - 5}{1} + 1 = 27$$

$$H_{out} = \frac{H_{in} + 2 \times padding - kernel\ size}{Stride} + 1$$

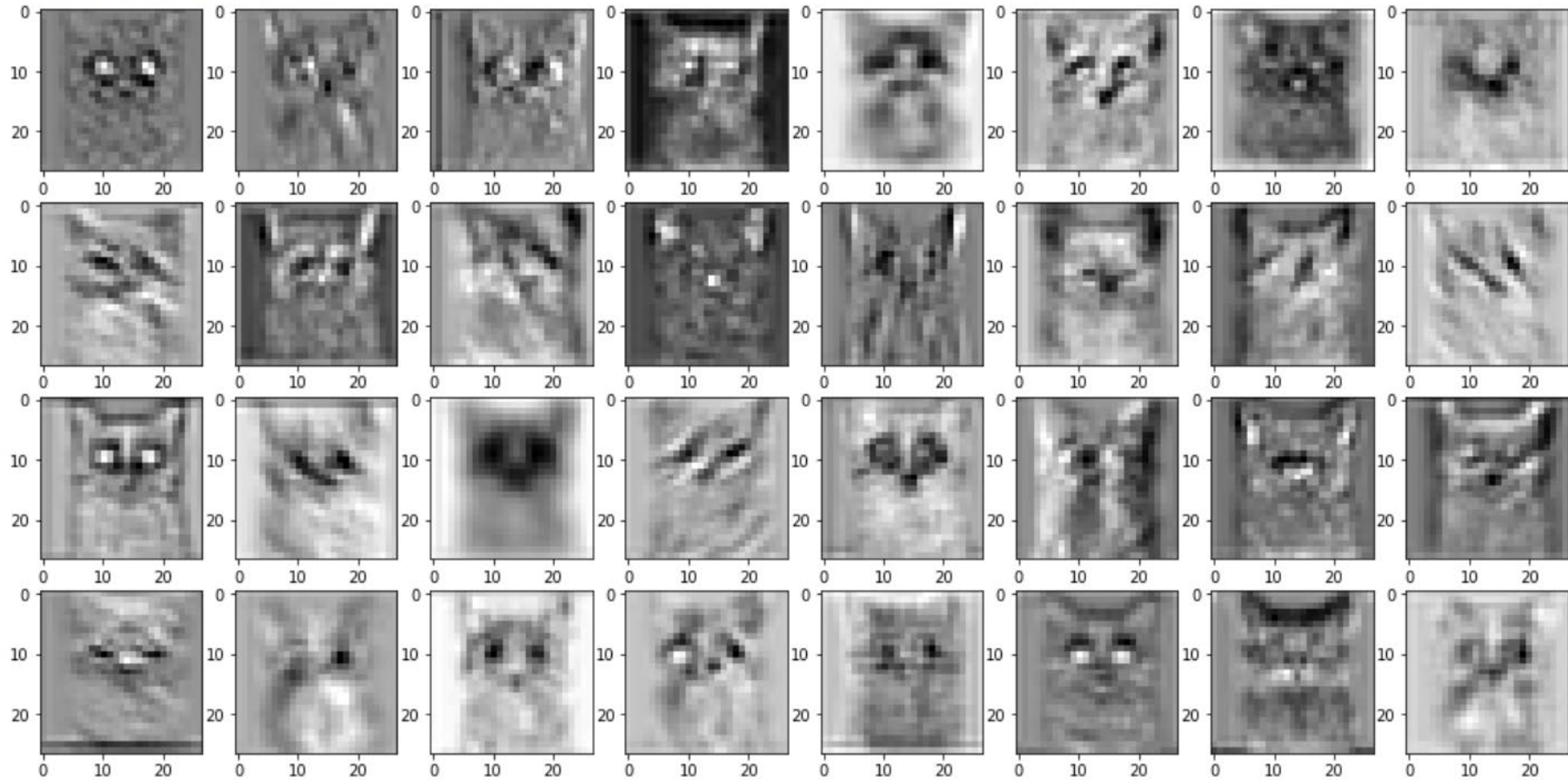
192 filters, each has 64 channels, are applied to the input feature map (with 64 channels)

```
AlexNet(
  (features): Sequential(
    (0): Conv2d(3, 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)
    (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)
    (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)
  )
)
```



Feature map after 2nd convolution

```
torch.Size([1, 192, 27, 27])
```



Apply max pooling to the feature map from 2nd convolution

features[4, 5]

```
[16]: conv2_pooling = model.features[4:6]
conv2_out1 = conv2_pooling(conv2_out)
print(conv2_out1.shape)
imgArray=conv2_out1[0].data.cpu().numpy()
fig=plt.figure(figsize=(18, 9))
for i in range(32): #visualize the first 32 channels
    fig.add_subplot(4, 8, i+1)
    plt.imshow(imgArray[i], cmap='gray')
plt.show()
```

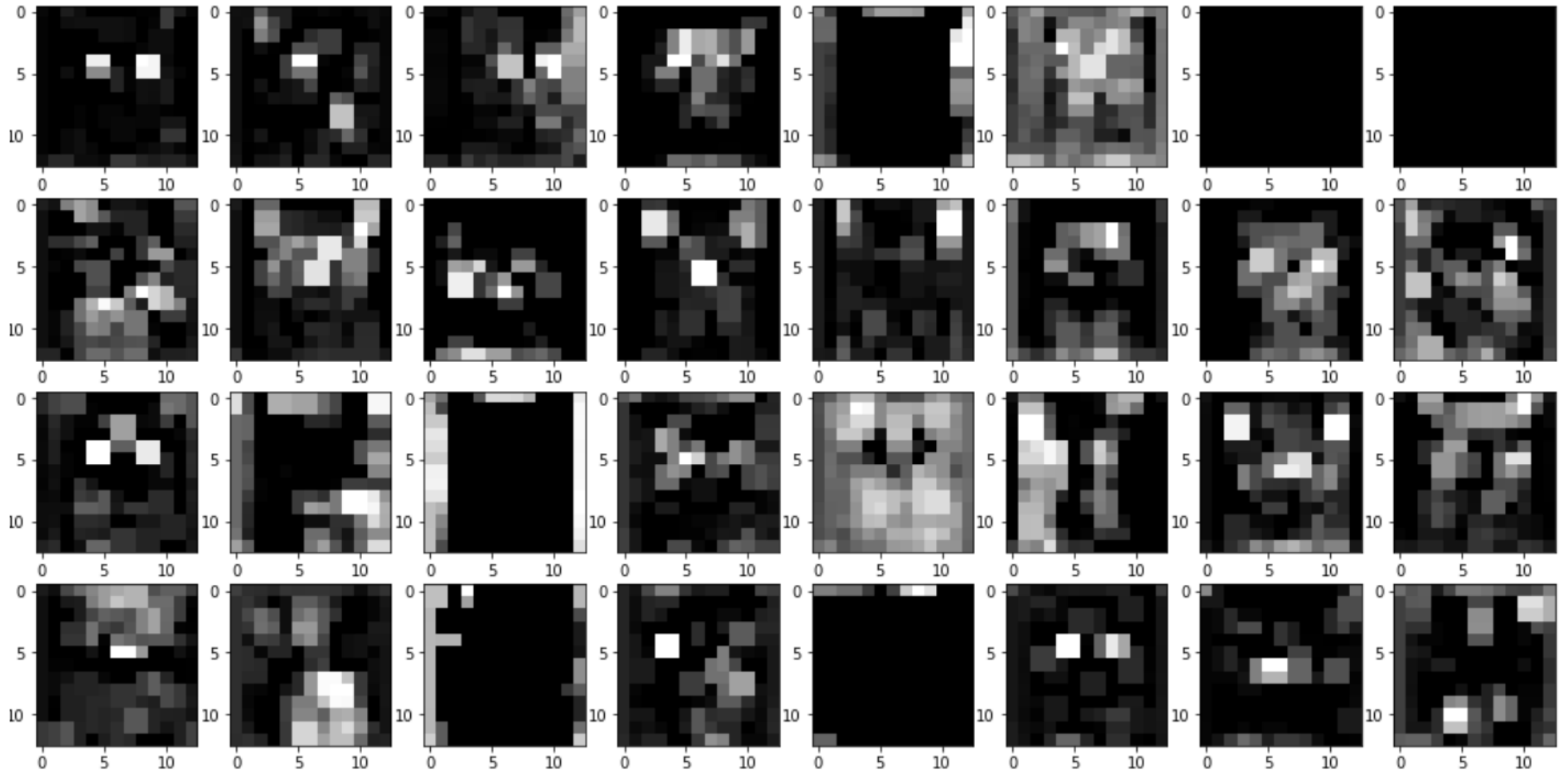
torch.Size([1, 192, 13, 13])

$$\frac{27 + 2 \times 0 - 3}{2} + 1 = 13$$

$$H_{out} = \frac{H_{in} + 2 \times padding - kernel\ size}{Stride} + 1$$

```
AlexNet(
  (features): Sequential(
    (0): Conv2d(3, 64, kernel_size=(11, 11), stride=(4, 4), padding=(0, 0))
    (1): ReLU(inplace=True)
    (2): MaxPool2d(kernel_size=3, stride=2, padding=0, dilation=1, ceil_mode=False)
    (3): Conv2d(64, 128, 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(128, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (7): ReLU(inplace=True)
    (8): Conv2d(256, 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)
  )
)
```


Feature map after 2nd convolution and max pooling



3rd convolution

```
[17]: conv3 = model.features[6]
conv3_out = conv3(conv2_out1)
print(conv3_out.shape)
imgArray=conv3_out[0].data.cpu().numpy()
fig=plt.figure(figsize=(18, 9))
for i in range(32): #visualize the first 32 channels
    fig.add_subplot(4, 8, i+1)
    plt.imshow(imgArray[i], cmap='gray')
plt.show()
```

torch.Size([1, 384, 13, 13])

After convolution, the output feature map has 394 channels

$$\frac{13 + 2 \times 1 - 3}{1} + 1 = 13$$

$$H_{out} = \frac{H_{in} + 2 \times padding - kernel\ size}{Stride} + 1$$

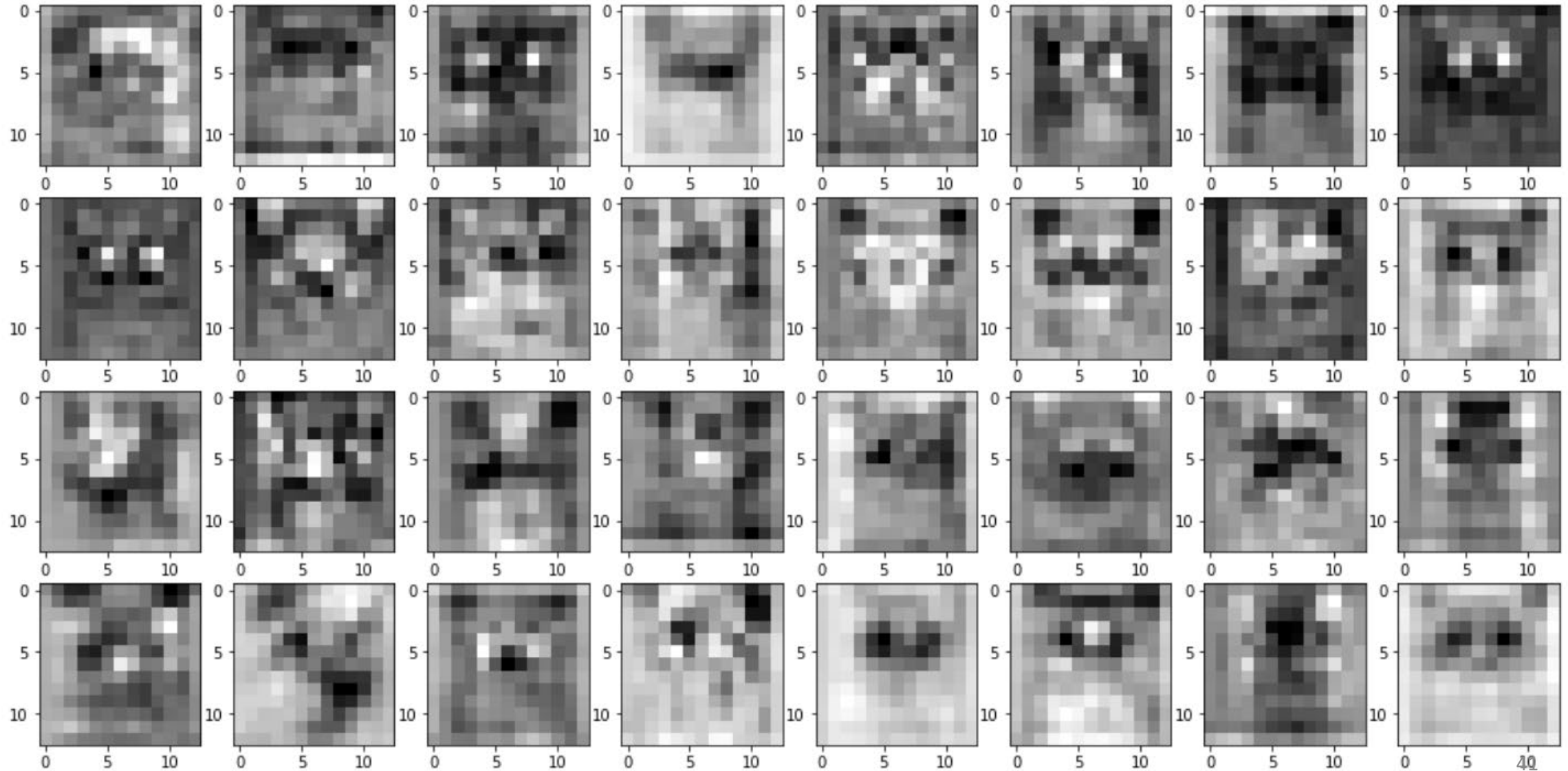
394 filters, each has 192 channels, are applied to the input feature map (with 192 channels)

```
AlexNet(
  (features): Sequential(
    (0): Conv2d(3, 64, kernel_size=(11, 11), stride=(4, 4), padding=(6, 6))
    (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)
  )
)
```



Feature map after 3rd convolution

```
torch.Size([1, 384, 13, 13])
```



Apply max pooling to feature map from 3rd convolution

features[7, 8]

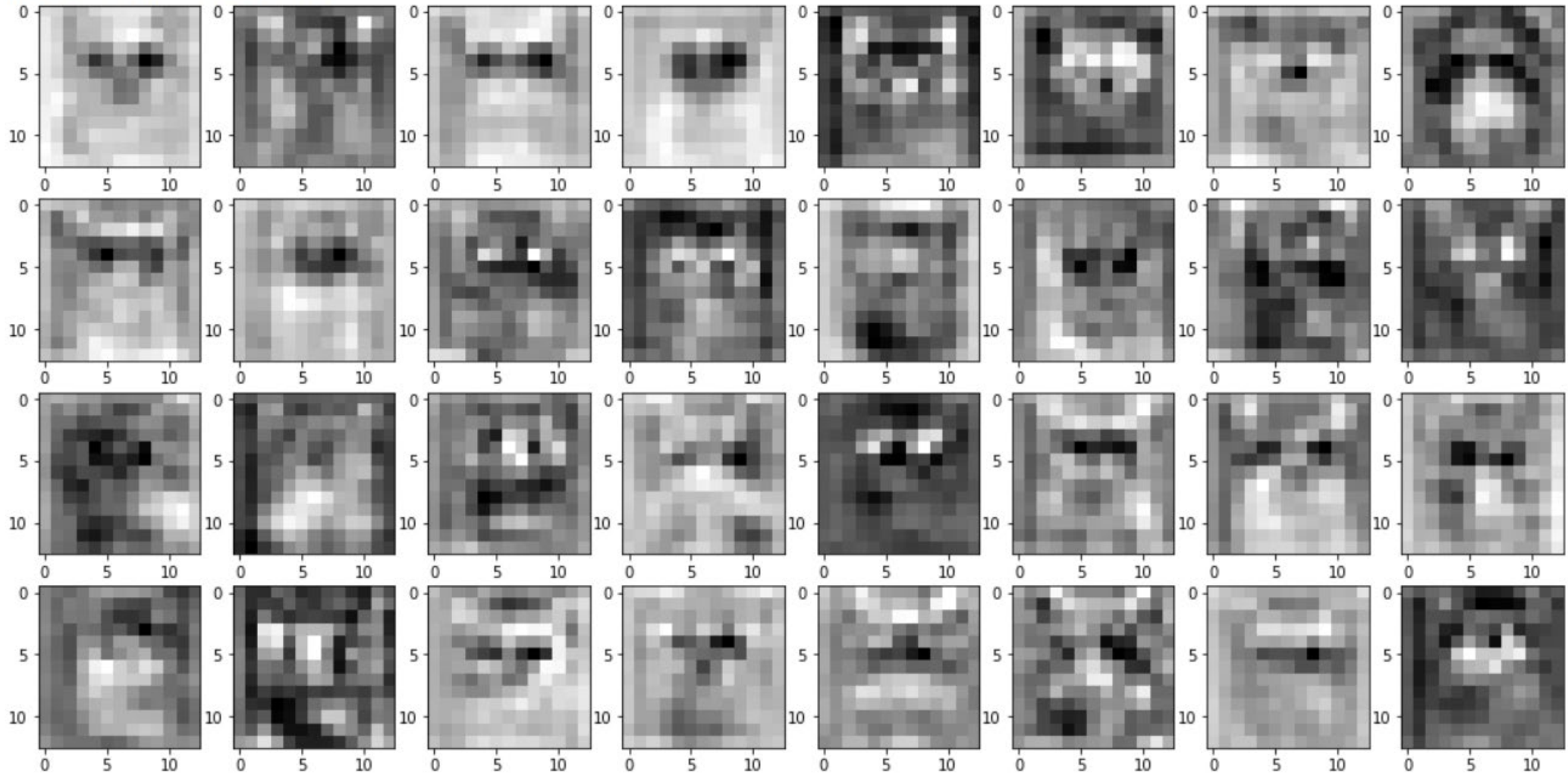
```
[18]: conv3_pooling = model.features[7:9]
conv3_out1 = conv3_pooling(conv3_out)
print(conv3_out1.shape)
imgArray=conv3_out1[0].data.cpu().numpy()
fig=plt.figure(figsize=(18, 9))
for i in range(32): #visualize the first 32 channels
    fig.add_subplot(4, 8, i+1)
    plt.imshow(imgArray[i], cmap='gray')
plt.show()

torch.Size([1, 256, 13, 13])
```

```
AlexNet(
  (features): Sequential(
    (0): Conv2d(3, 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, 128, 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(128, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
    (7): ReLU(inplace=True)
    (8): Conv2d(256, 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)
  )
)
```

Feature map after 3rd convolution and max pooling

```
torch.Size([1, 256, 13, 13])
```



Flatten

```
[19]: WholeConvLayers = model.features
      out1 = WholeConvLayers(imageTensor.to(device))
      print(out1.shape)

      AvgPoolLayer = model.avgpool
      out2 = AvgPoolLayer(out1)
      print(out2.shape)

      torch.Size([1, 256, 6, 6])
      torch.Size([1, 256, 6, 6])
```

After last convolution and max pooling, the output feature map has 256 channels

$$256 \times 6 \times 6 = 9216$$

```
(features): Sequential(
  (0): Conv2d(3, 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=1000, bias=True)
)
```


Practice: Draw the structure of AlexNet

```
(features): Sequential(
  (0): Conv2d(3, 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=1000, bias=True)
)
```