Deep learning
episode 2
Computer vision applications

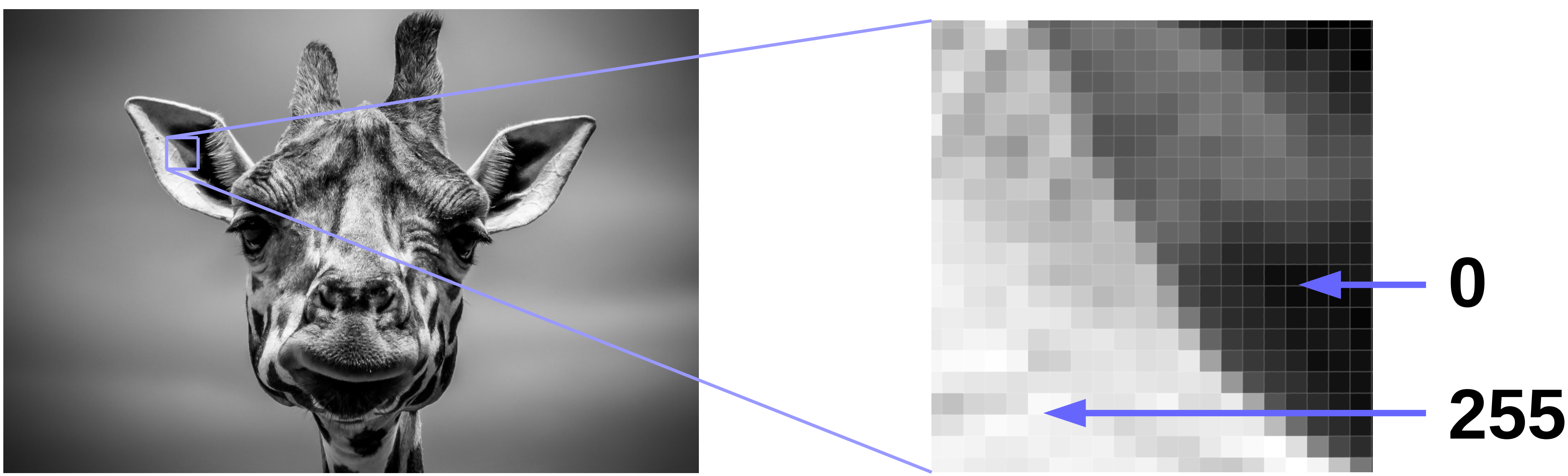
Yandex
Data Factory

LAMBDA

British Hedgehog
Preservation Society

Images

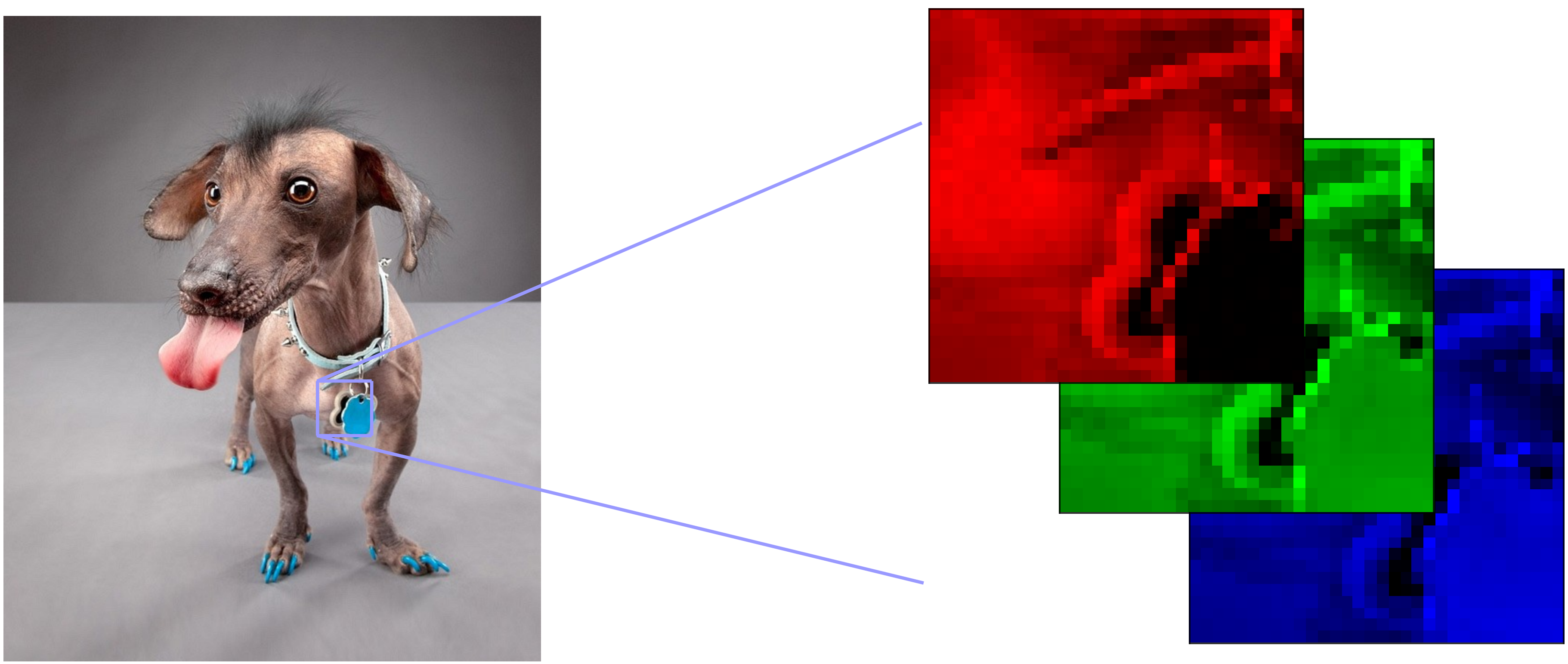
- Grayscale image is a matrix of pixels [H x W]
    - Pixels = **pic**ture **el**ements
- Each pixel stores number [0,255] for brightness



Slide from Andrey Zimovnov's “Deep learning for computer vision”

Images

- RGB image is a 3d array [HxWx3] or [3xHxW]
  - Each pixel stores **R**ed, **G**reen & **B**lue color values [0,255]



Slide from Andrey Zimovnov's “Deep learning for computer vision”

Image recognition

“Dog”

Image recognition

“Gray wall”

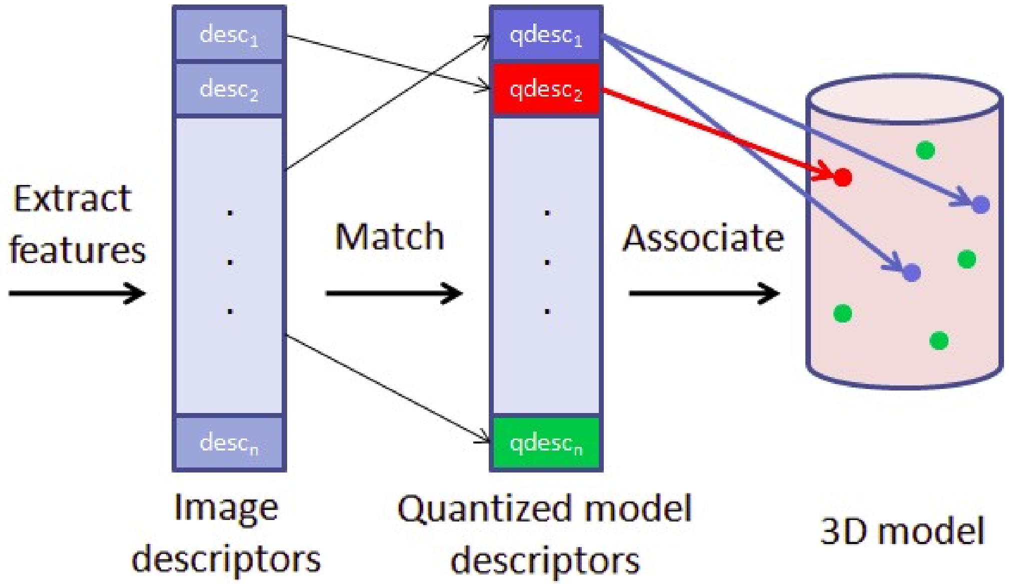
“Dog tongue”

“Dog”

<a particular kind of dog>

“Animal sadism”

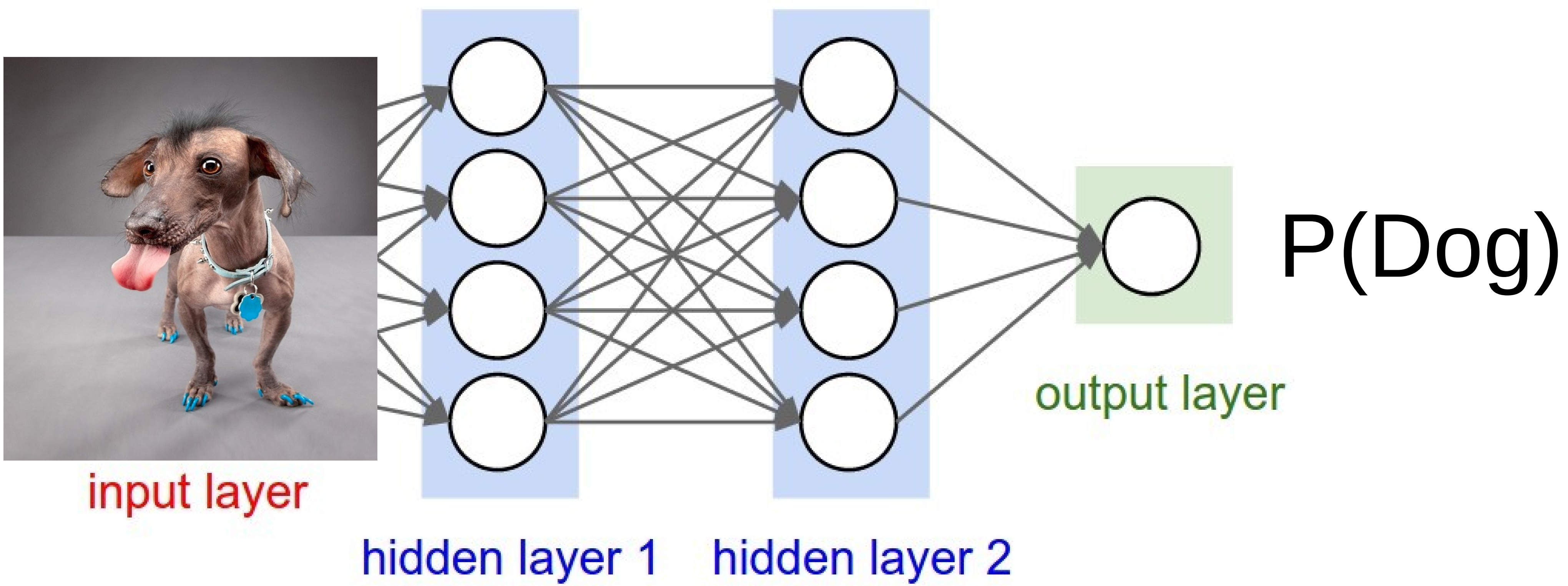
Classical approach



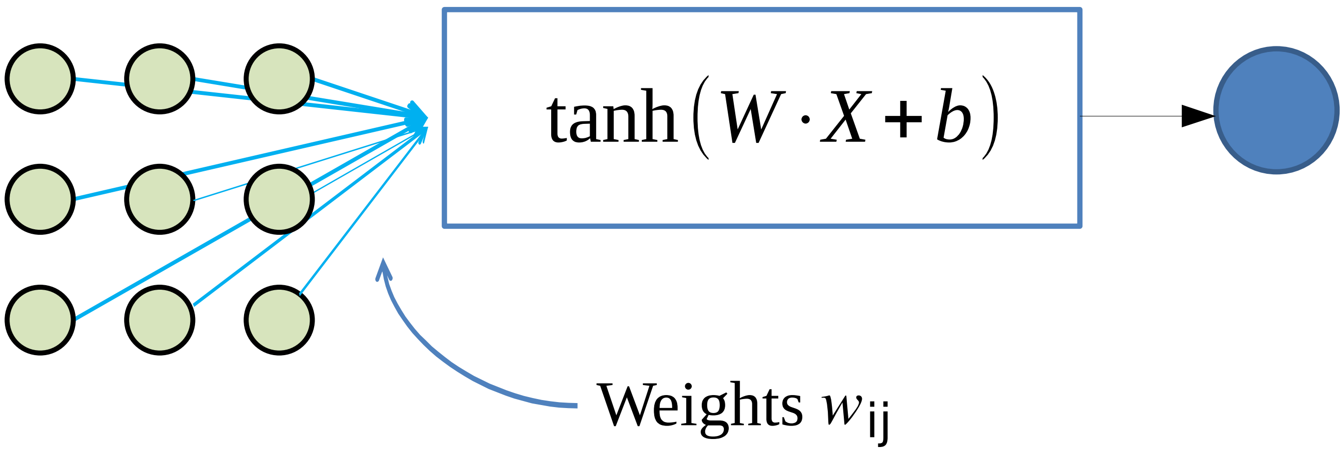
“Dog”

Guess what we're going to do now?

NN approach

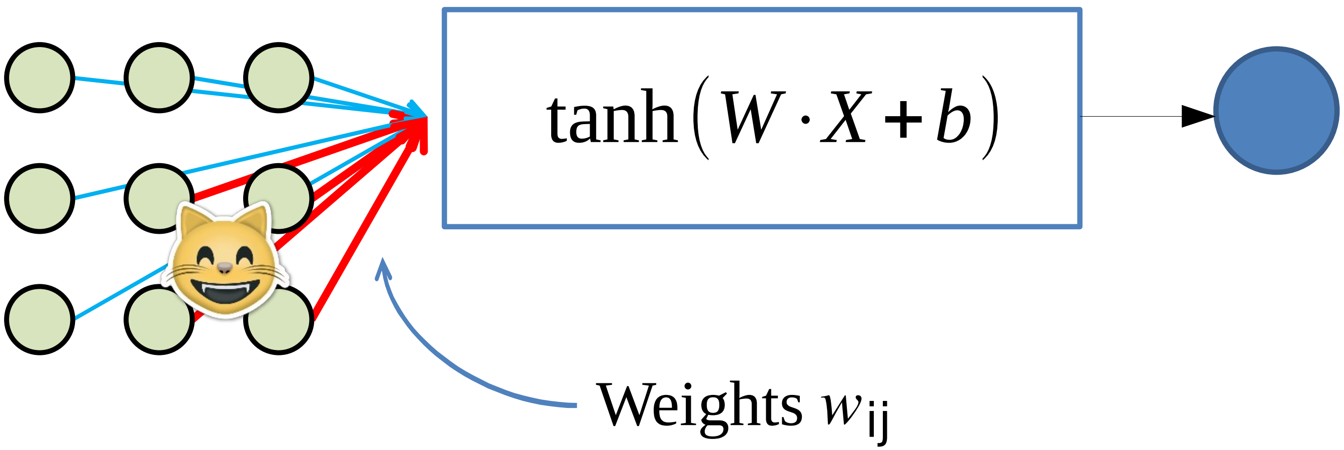


Problem with images



Slide from Andrey Zimovnov's “Deep learning for computer vision”

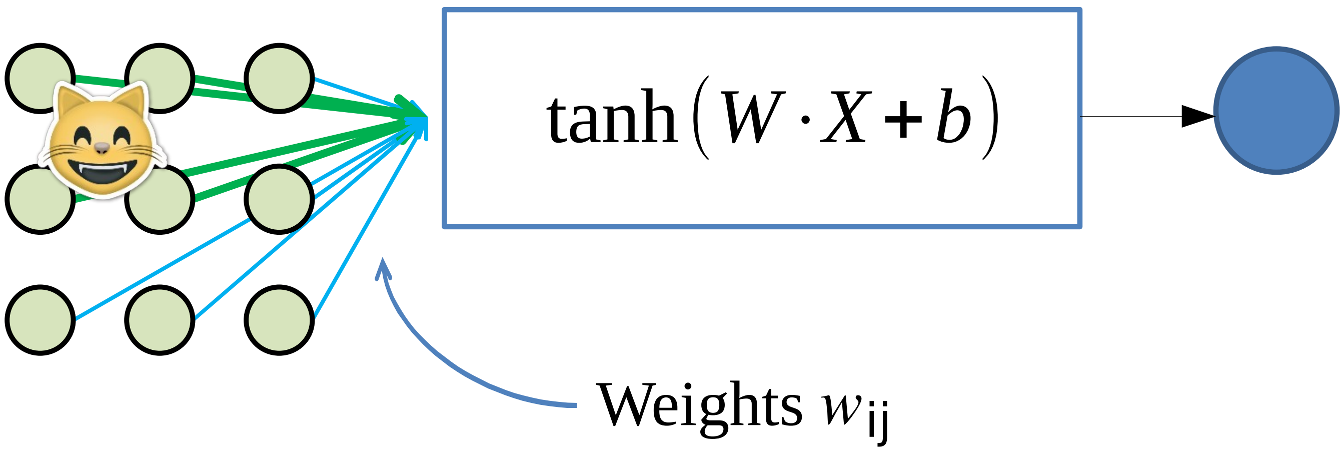
Problem with images



On this object, you will train red weights to react on cat face

Slide from Andrey Zimovnov's “Deep learning for computer vision”

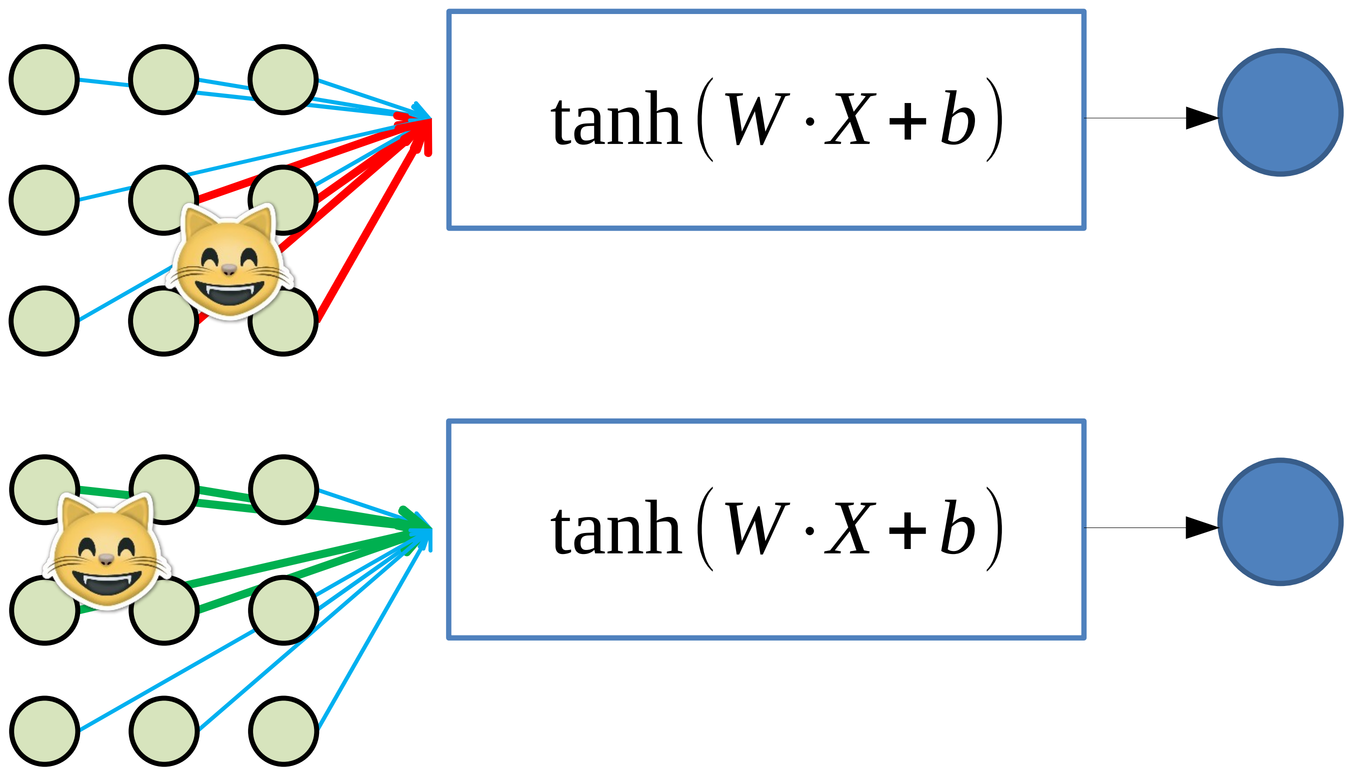
Problem with images



On this object, you will train green
weights to react on cat face

Slide from Andrey Zimovnov's “Deep learning for computer vision”

Problem with images



You network will have to learn those two cases separately!

Worst case: one neuron per position.

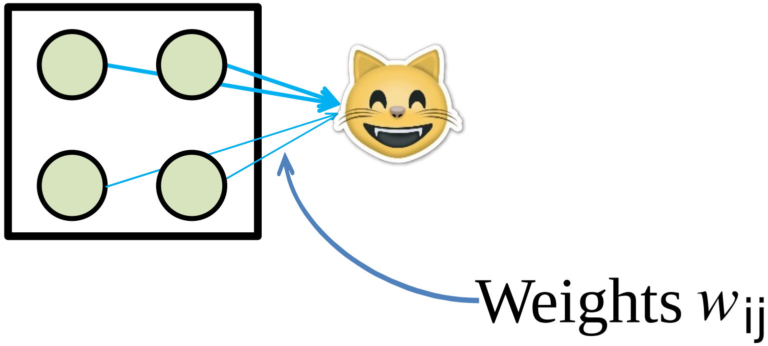
Slide from Andrey Zimovnov's “Deep learning for computer vision”

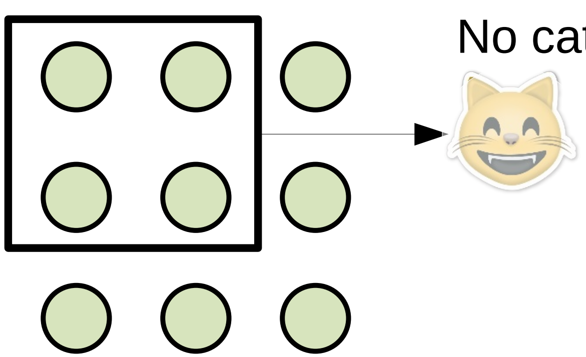
Problem

Idea: force all these “cat face” features
to use **exactly same weights**,
shifting weight matrix each time.

Same features for each spot

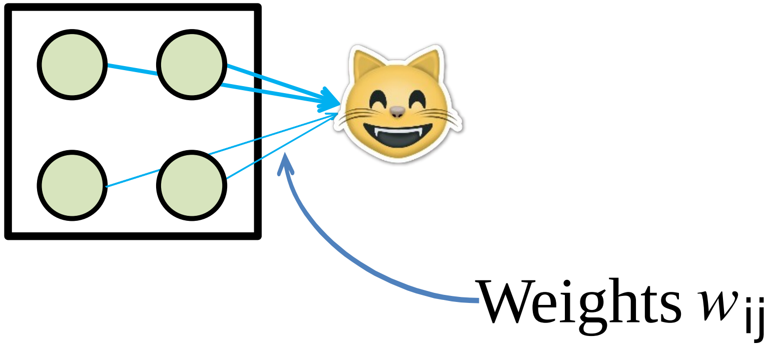
Portable cat detector pro!

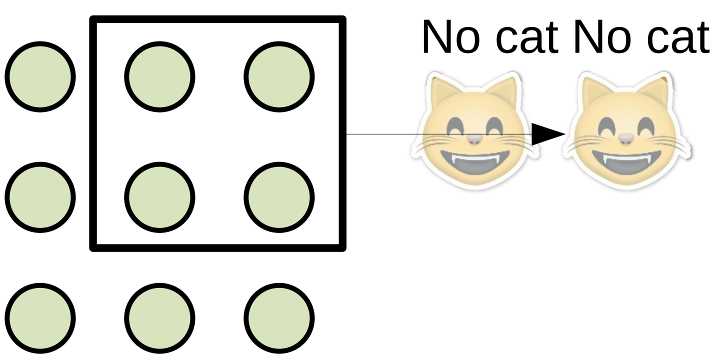




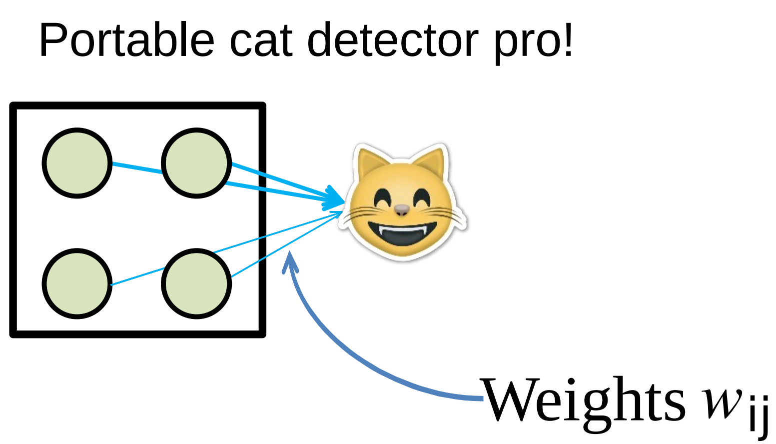
Same features for each spot

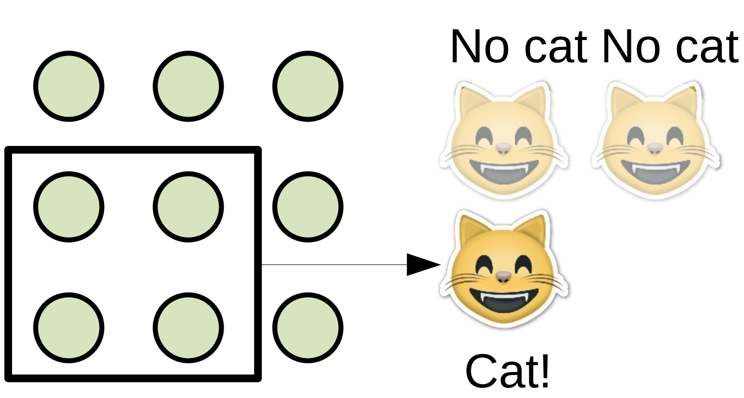
Portable cat detector pro!





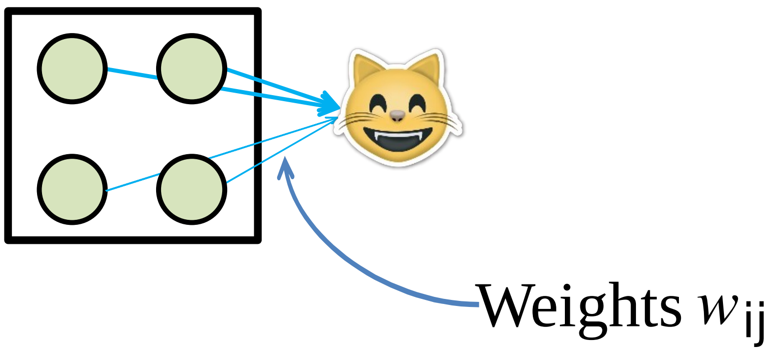
Same features for each spot

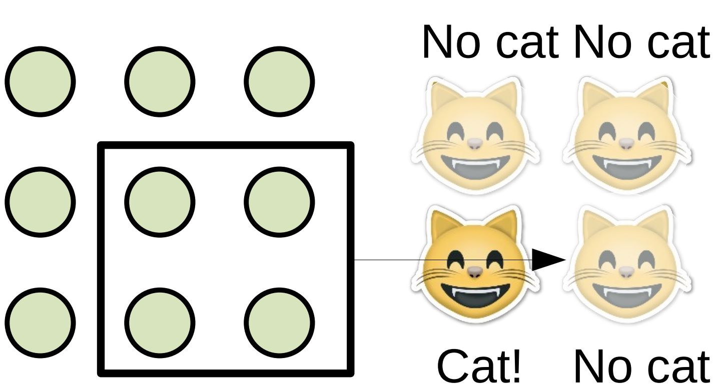




Same features for each spot

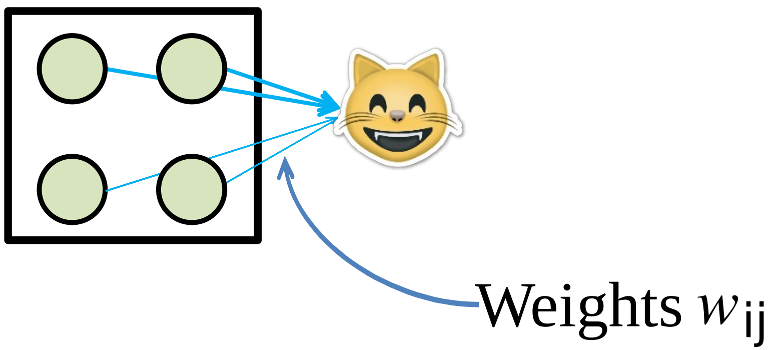
Portable cat detector pro!

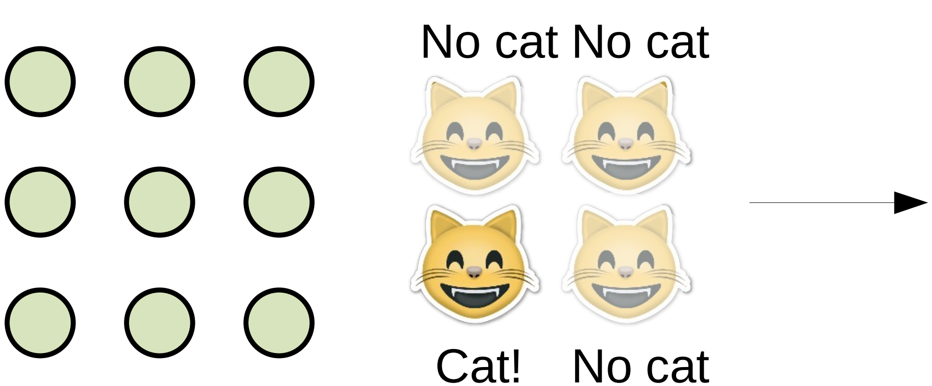




Same features for each spot

Portable cat detector pro!

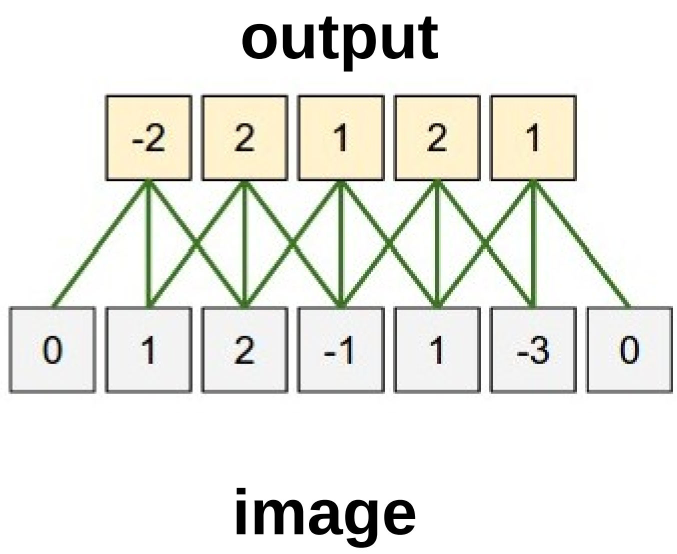


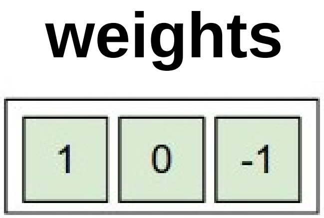


There's a cat here!

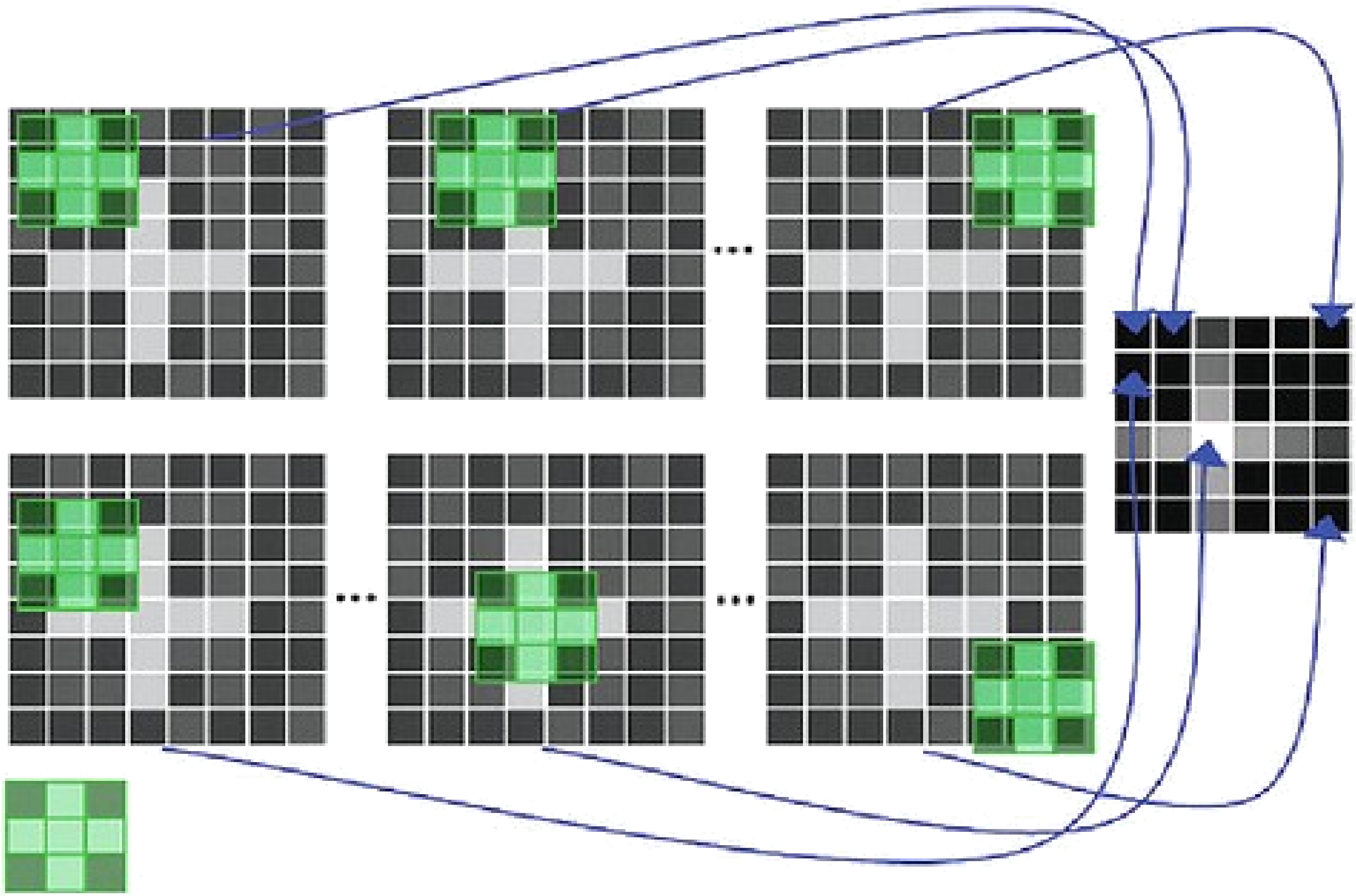
Convolution

- Apply same weights to all patches



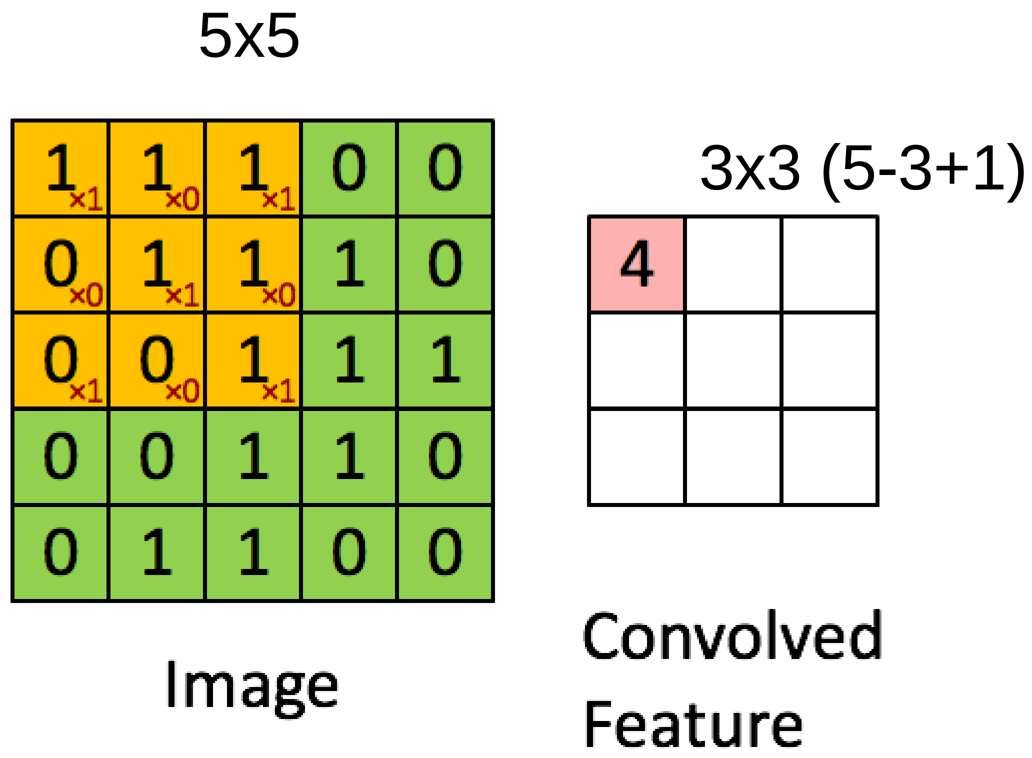


Convolution



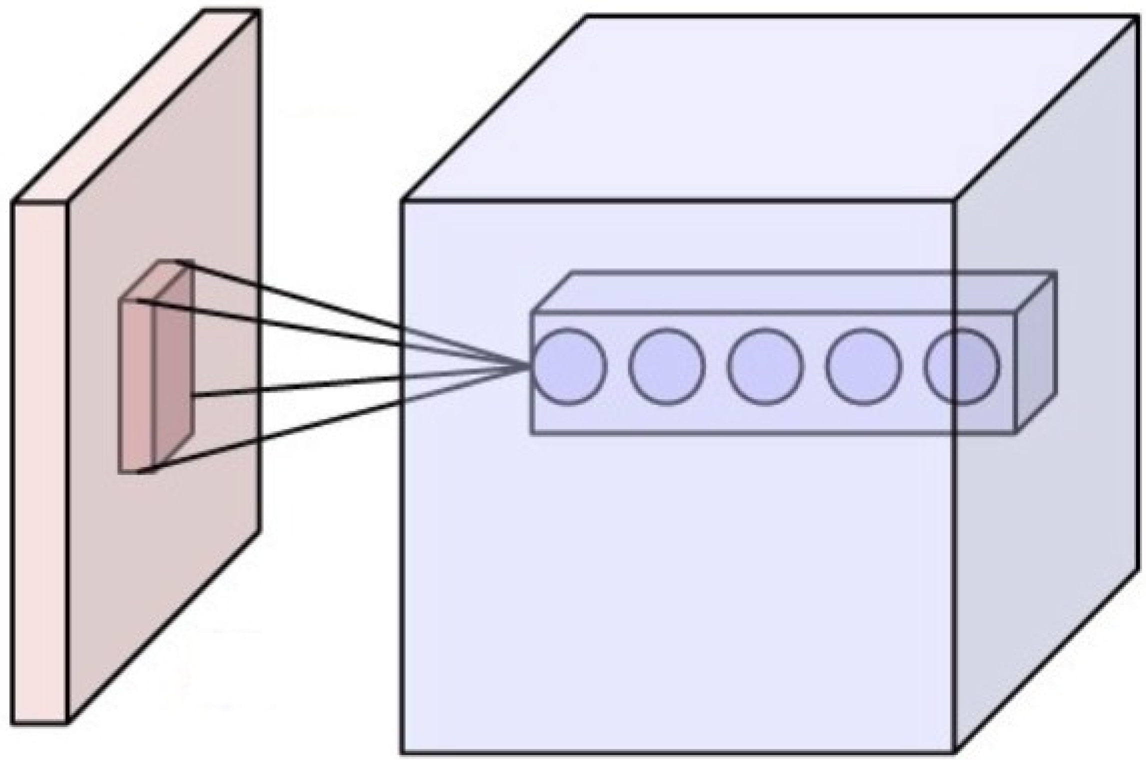
apply same filter to all patches

Convolution



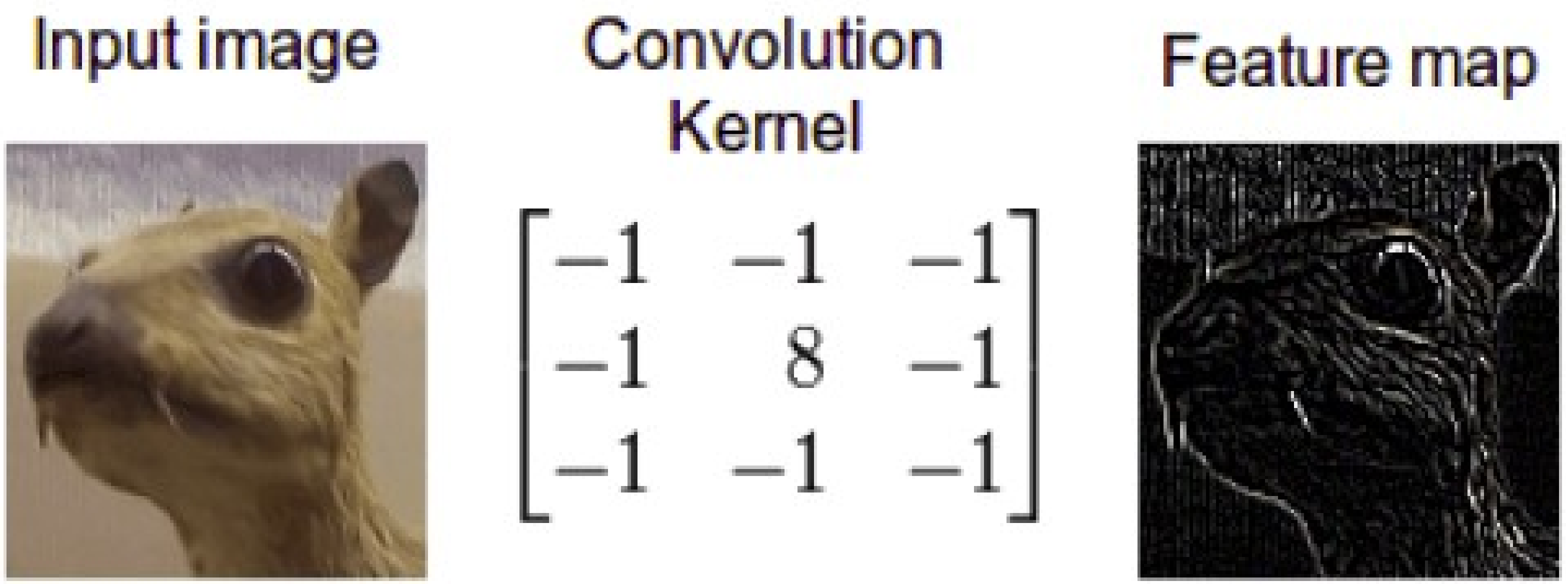
Intuition: how cat-like is this square?

Convolution



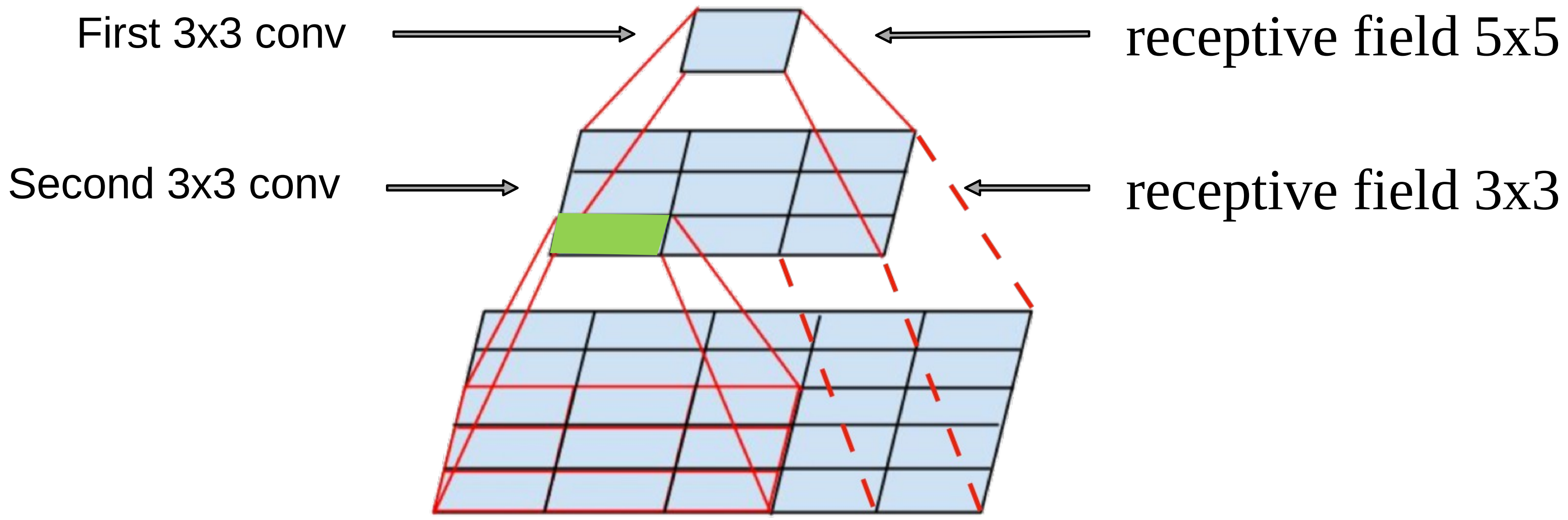
Intuition: how cat-like is this square?

Convolution



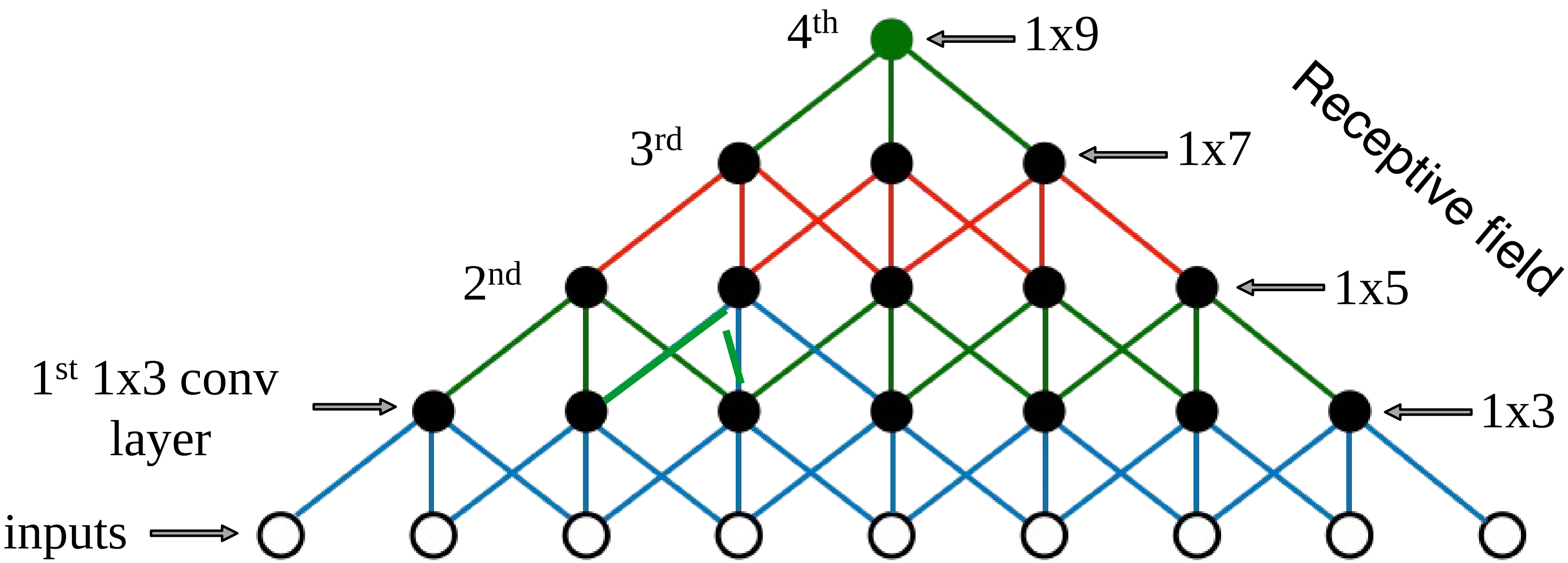
Intuition: how **edge-like** is this square?

Receptive field



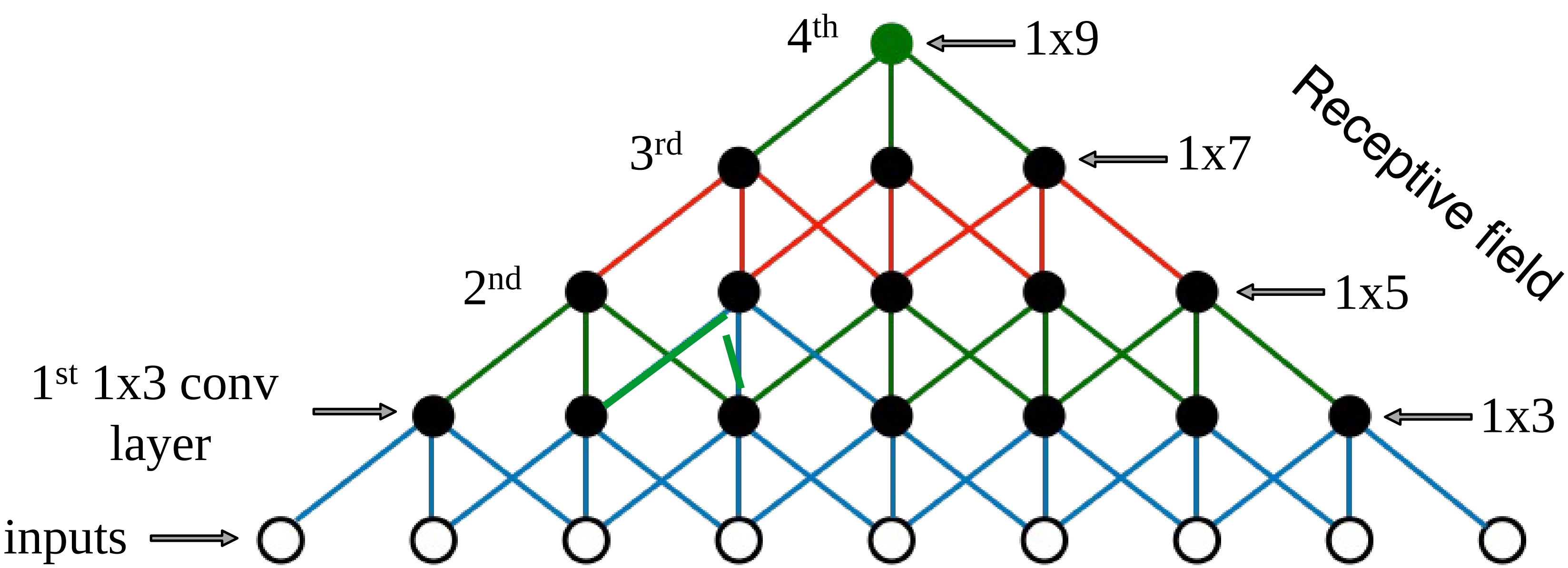
We can recognize larger objects by stacking several small convolutions!

Receptive field



Q: how many 3x3 convolutions we should use to recognize a 100x100px cat

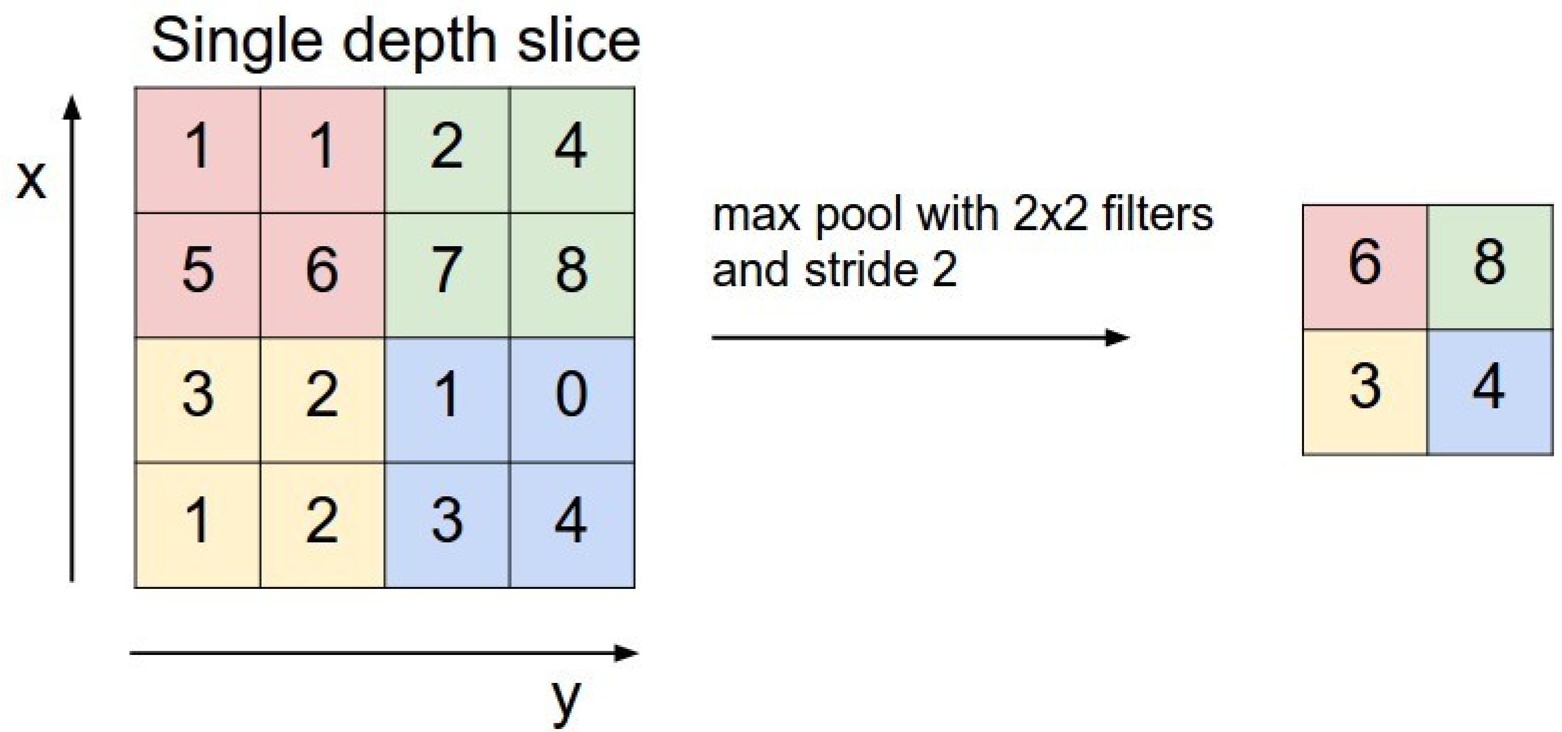
Receptive field



Q: how many 3x3 convolutions we should use to recognize a 100x100px cat

A: around 50... we need to increase receptive field faster!

Pooling



Intuition: What is the max cat-likelihood over this area?

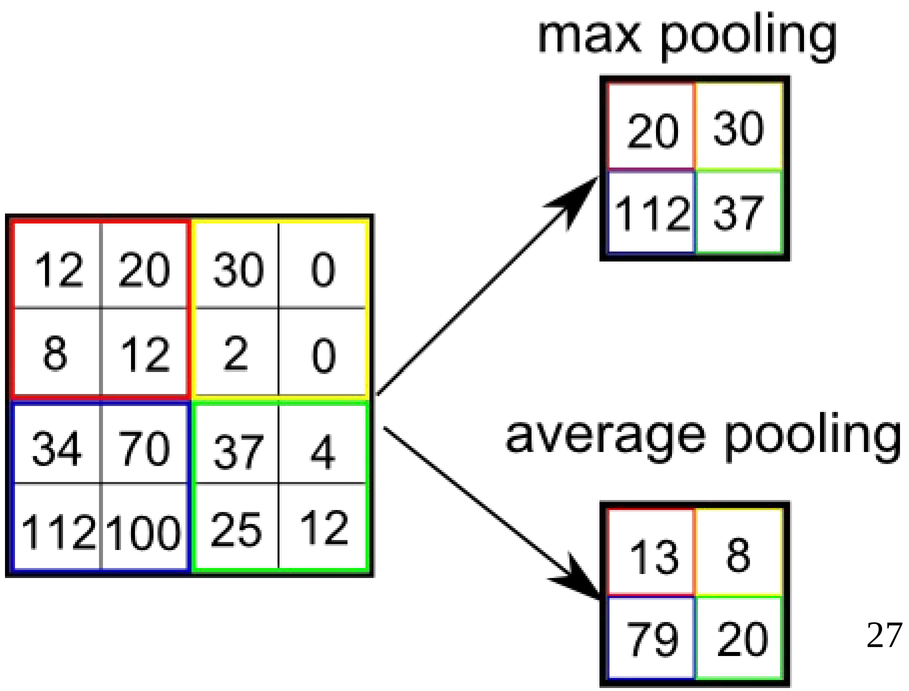
Pooling

Motivation:

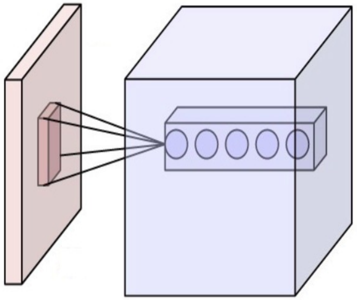
- Reduce layer size by a factor
- Make NN less sensitive to small image shifts

Popular types:

- Max
- Mean(average)



Convolution

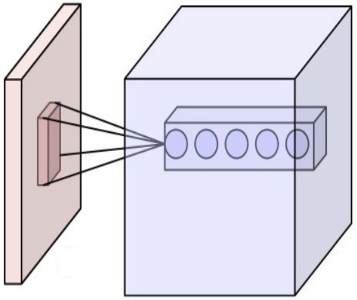


?!

Filters: 100x(3x5x5)

Image : 3 (RGB) x 100 px x 100 px

Convolution



100x96x96

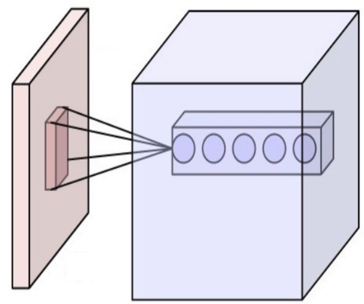
~10^6

Filters: 100x(3x5x5)

Image : 3 (RGB) x 100 px x 100 px

Somewhat too many!

Convolution



100x96x96

~10^6

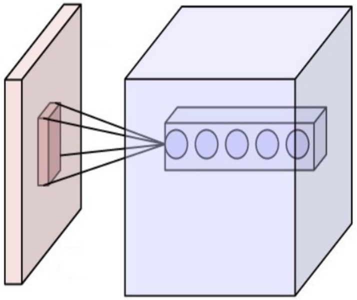
Filters: 100x(3x5x5)

Image : 3 (RGB) x 100 px x 100 px

100x96x96 → pool 3x4 → ???

Convolution

→



→ 100x96x96

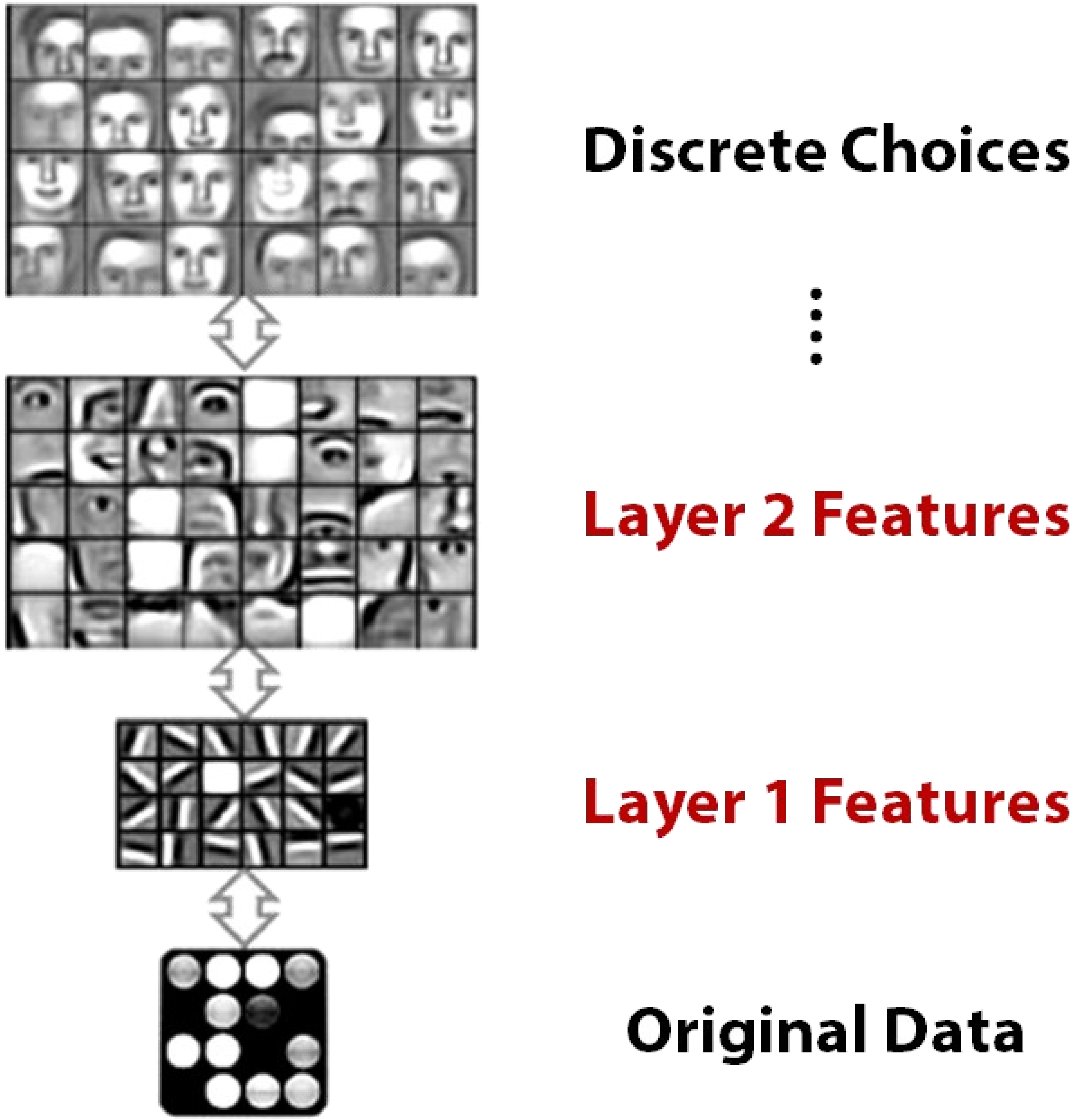
~10^6

Filters: 100x(3x5x5)

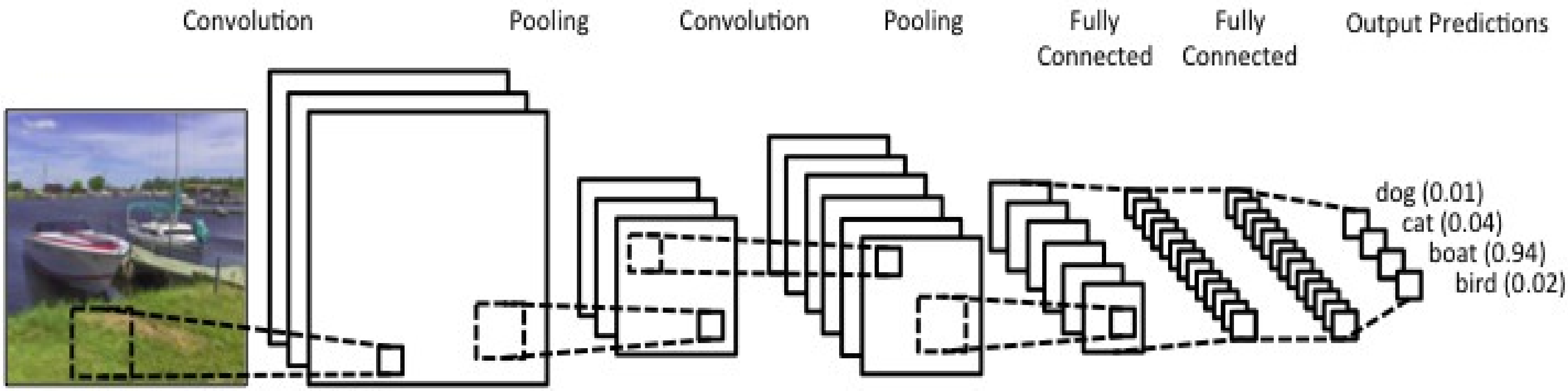
Image : 3 (RGB) x 100 px x 100 px

100x96x96 → pool 3x4 → 100x32x32

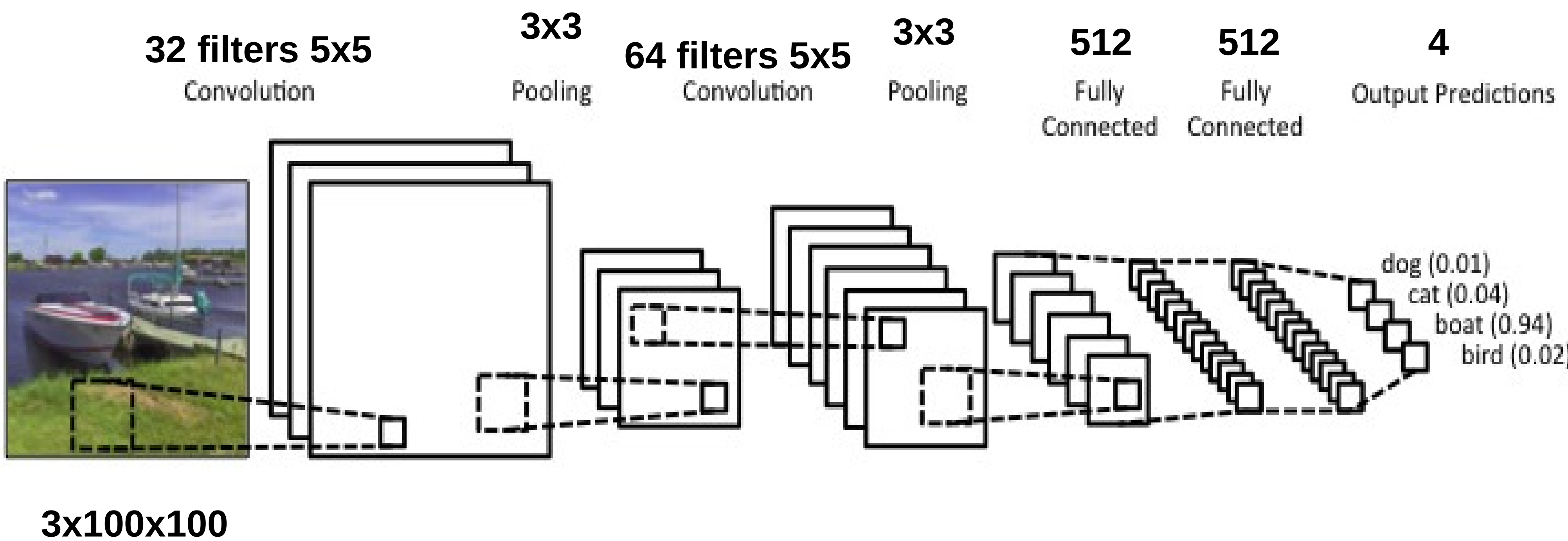
~10^5


Discrete Choices
Layer 2 Features
Layer 1 Features
Original Data

Convolutional NNs



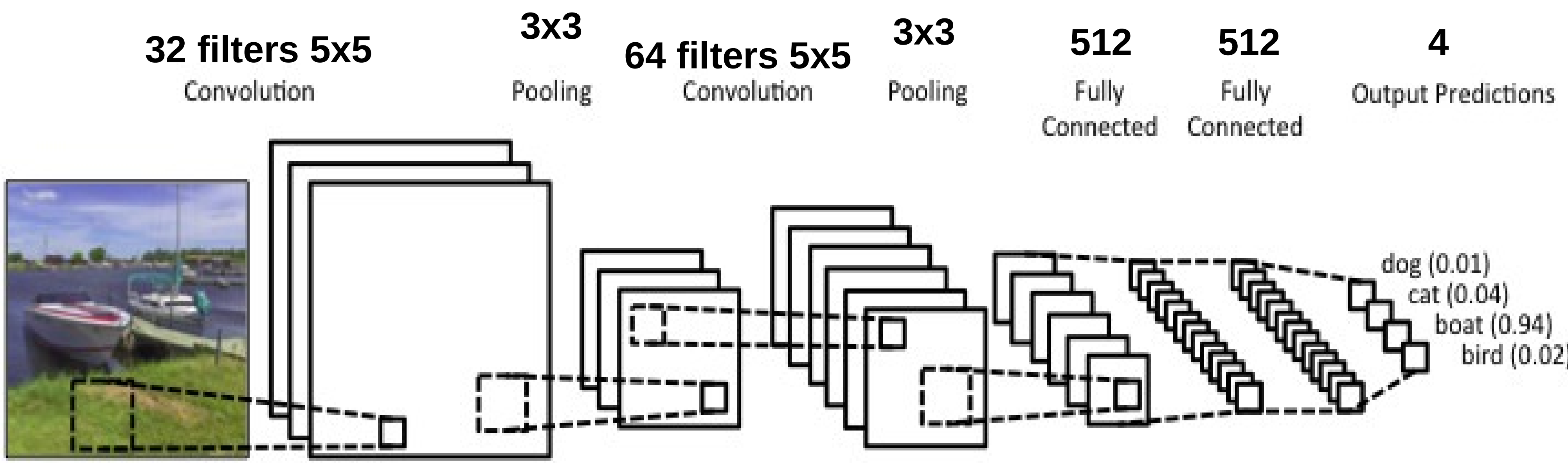
Convolutional NNs



Quiz:

1) What is the output shape **after second pooling**

Convolutional NNs



3x100x100

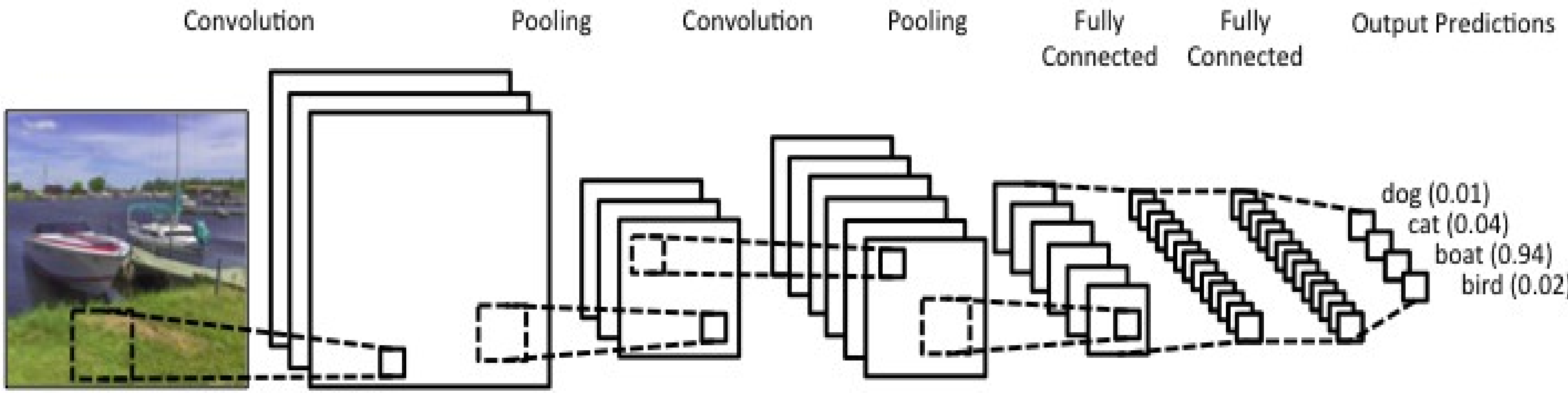
Quiz:

2) How many image pixels does **one cell** after **second convolution** depend on?

Convolutional NNs

3x3 **3x3**

32 filters 5x5 **64 filters 5x5** **512** **512** **4**



3x100x100

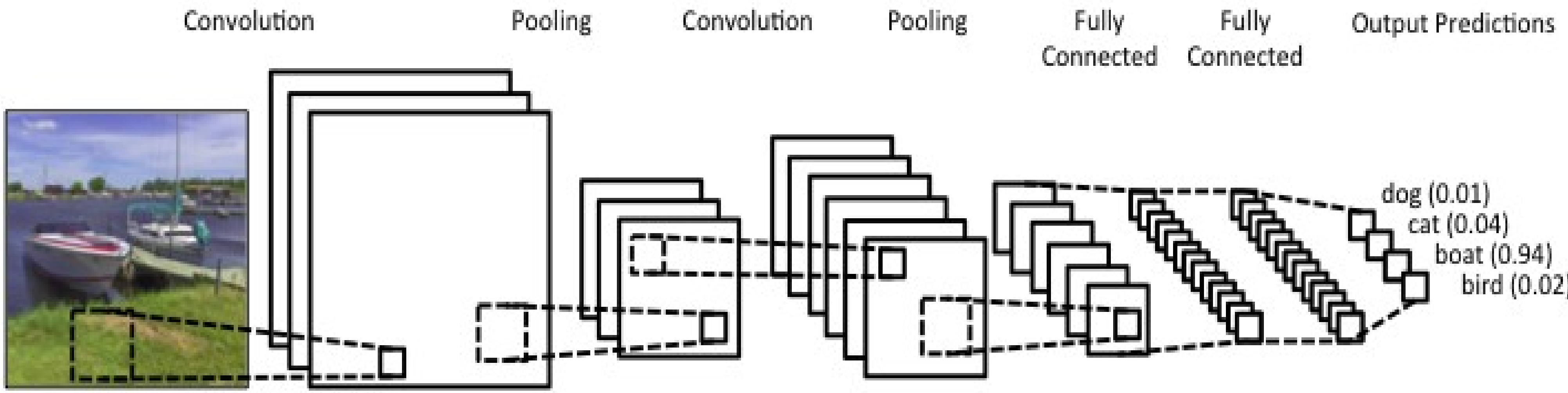
Quiz:

3) Which layer is hardest to compute?

4) Which layer has most independent parameters?

Convolutional NNs

32 filters 5x5 **3x3** **64 filters 5x5** **3x3** **512** **512** **4**



3x100x100

Quiz:

3) Which layer is hardest to compute?: **first conv**

4) Which layer has most independent parameters? **first dense**

Problem with large networks

What you sign for if you stack 1000 layers:

- MemoryError(0x...)
- Gradients can vanish
- Gradients can explode
- Activations can vanish
- Activations can explode

Problem with large networks

What you sign for if you stack 1000 layers:

- MemoryError(0x...)
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- Gradients can explode
- **Activations can vanish**
- **Activations can explode**

How do we fix these?

Problem with large networks

What you sign for if you stack 1000 layers:

- MemoryError(0x...)
- Gradients can vanish
- Gradients can explode
- **Activations can vanish**
- **Activations can explode**

Batch normalization
or similar

Problem with large networks

What you sign for if you stack 1000 layers:

- MemoryError(0x...)
- **Gradients can vanish**
- **Gradients can explode**
- Activations can vanish
- Activations can explode

Next week

Batch normalization
or similar

Data augmentation

- Idea: we can get N times more data by tweaking images.
- If you rotate cat image by 15°, it's still a cat

- Rotate, crop, zoom, flip horizontally, add noize, etc.
- Sound data: add background noizes

Other CV applications

Real computer vision starts when
image classification is no longer enough.

Bounding box regression

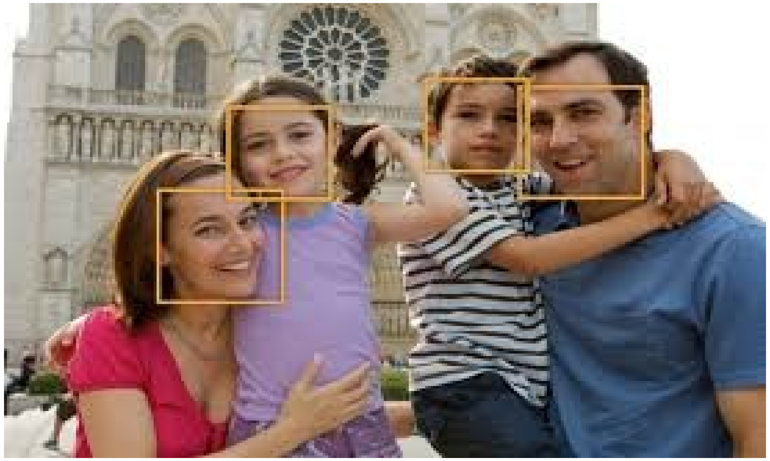
Predict object bounding box

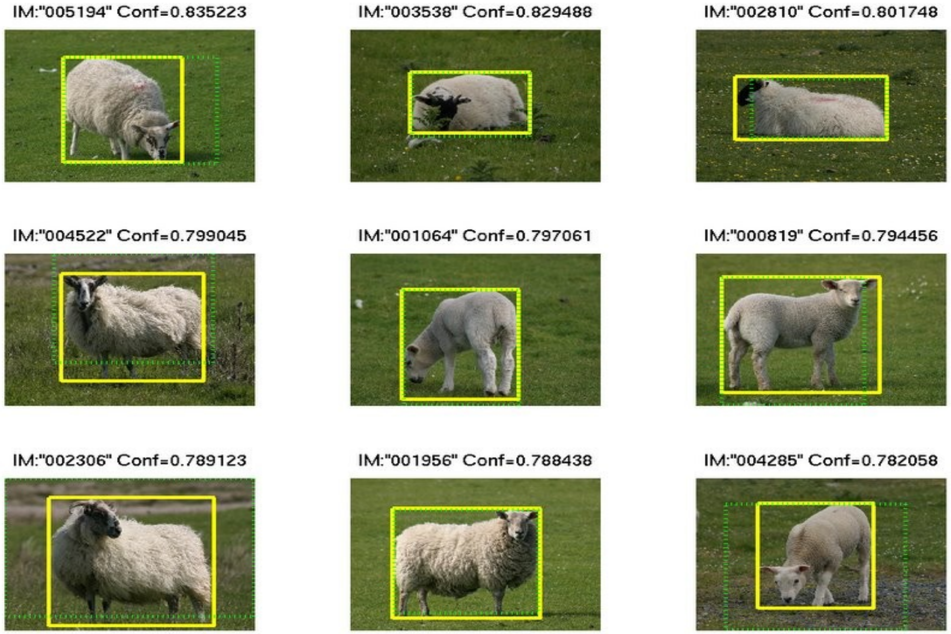
(x0,y0,w,h)

or several bounding boxes for multiple objects.

Applications examples:

- Face detection @ cameras
- Surveillance cameras
- Self-driving cars



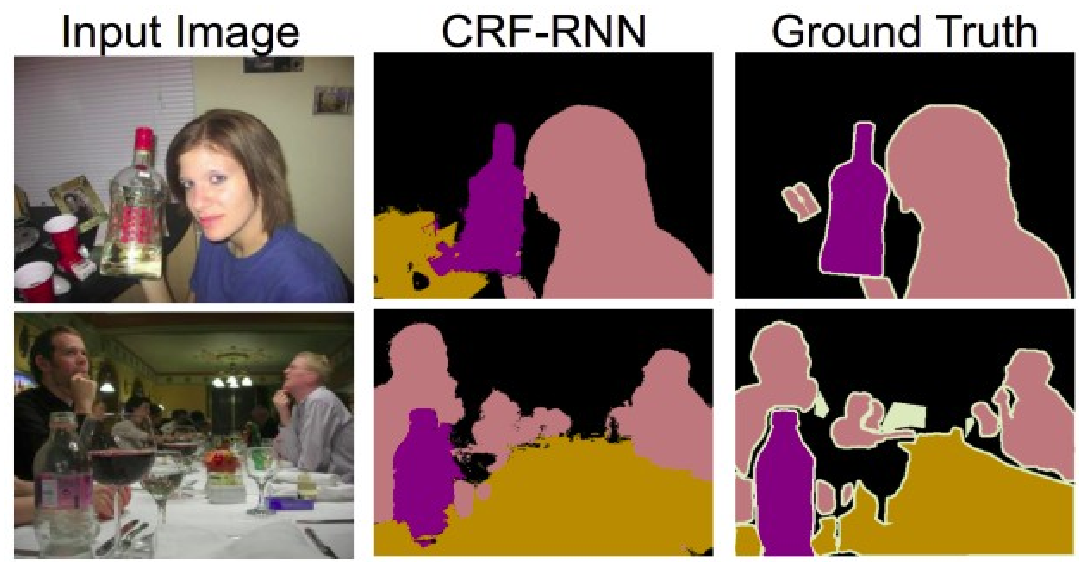


Segmentation

Predict class for each pixel

(fully-convolutional networks)

Applications examples:
- Moar surveillance
- Brain scan labeling
- Map labeling



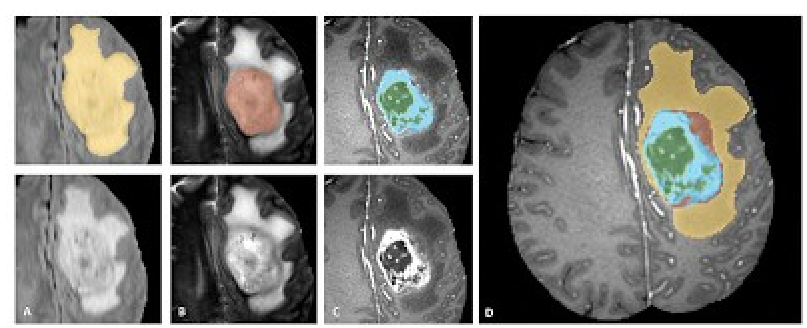
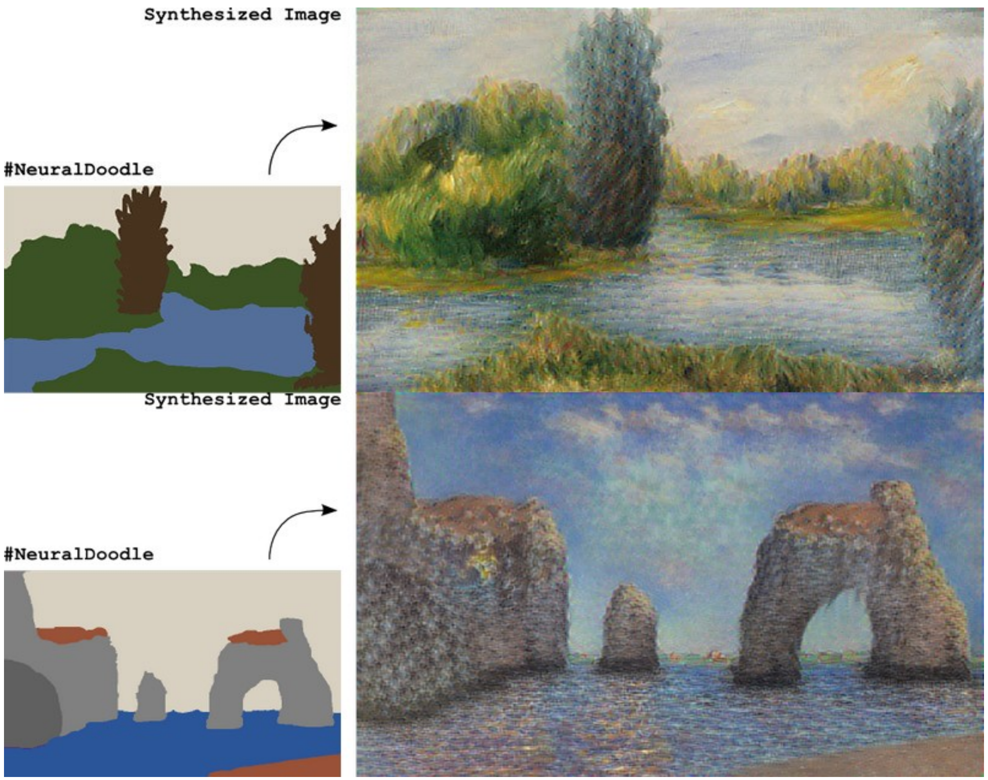


Image generation/transformation

- **Generation:** Given a set of reference images, learn to generate new images, resembling those you were given.

- **Transformation:** Given a set of reference images, learn to convert other images into ones resembling the reference set.



Neural Doodle
(D. Ulyanov et al.)

Image tagging
Image captioning
Image retrieval
Image encoding
Image morphing
Image encoding
Image upscaling
Object tracking on video
Video processing
Video interpolation

Fine-tuning
Adversarial Networks
Variational Autoencoders
Knowledge transfer
Domain adaptation
Online learning
Explaining predictions
Soft targets
Scene reconstruction
3D object retrieval
Classifier optimization

Nuff

Let's train some CNNs!