Convolutional neural network (CNN) for computer vision

Insop

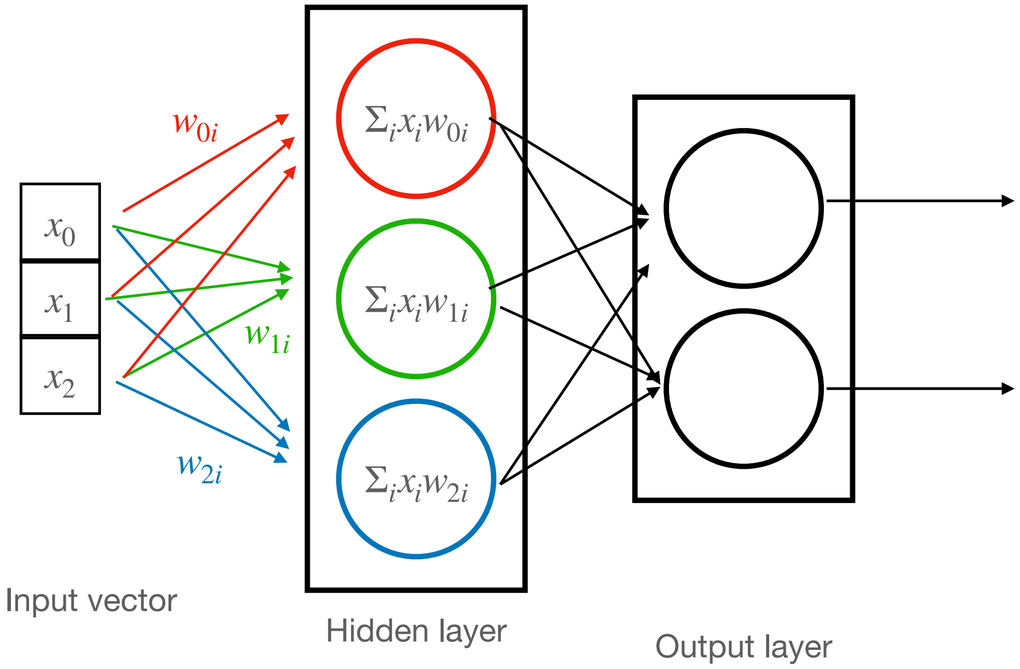
Agenda

1. Review: Neural Network
2. Image classification, motivation
3. Convolutional neural network
4. CNN architecture
5. Transfer learning

1. Review: Neural Network

Neural network

- Each neuron: sum of weighted input passed to non-linear function
- Layer: multiple neurons
- Multiple layers: connecting many layers
- Neurons in each layers are connected



$$\begin{bmatrix} w_{00}x_0 + w_{01}x_1 + w_{02}x_2 \\ w_{10}x_0 + w_{11}x_1 + w_{12}x_2 \\ w_{20}x_0 + w_{21}x_1 + w_{22}x_2 \end{bmatrix} = \begin{bmatrix} w_{00} & w_{01} & w_{02} \\ w_{10} & w_{11} & w_{12} \\ w_{20} & w_{21} & w_{22} \end{bmatrix} \begin{bmatrix} x_0 \\ x_1 \\ x_2 \end{bmatrix}$$

2. Image classification, motivation

Deep learning breakthrough

- Alexnet started deep learning breakthrough using CNN in Imagenet competition in 2012
- Since then CNN is used every where in computer vision applications

Object detection

Source:
https://arxiv.org/pdf/1506.01497.pdf

Image segmentation

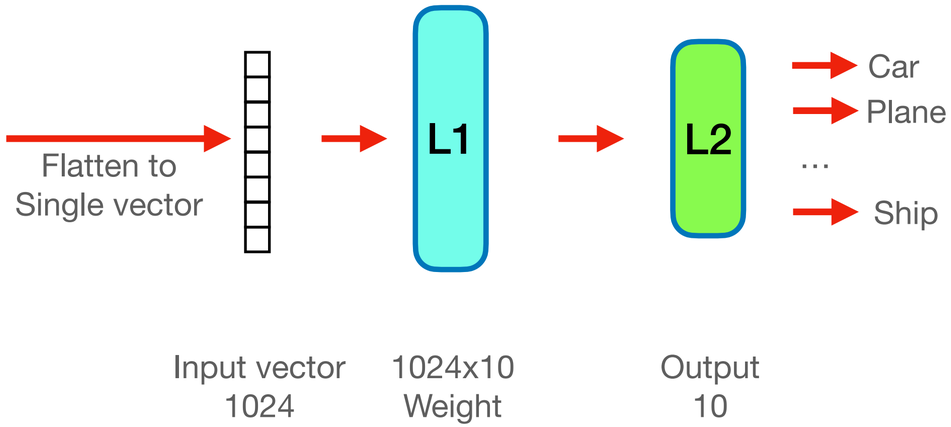
Source:
https://arxiv.org/pdf/1703.06870.pdf

Image classification

Fully connected neural network?

- Image classification with neural network
- Flatten image and use it as input
- example>
  - Input: 32x32 image
  - Output: 10 class

32x32 with single color



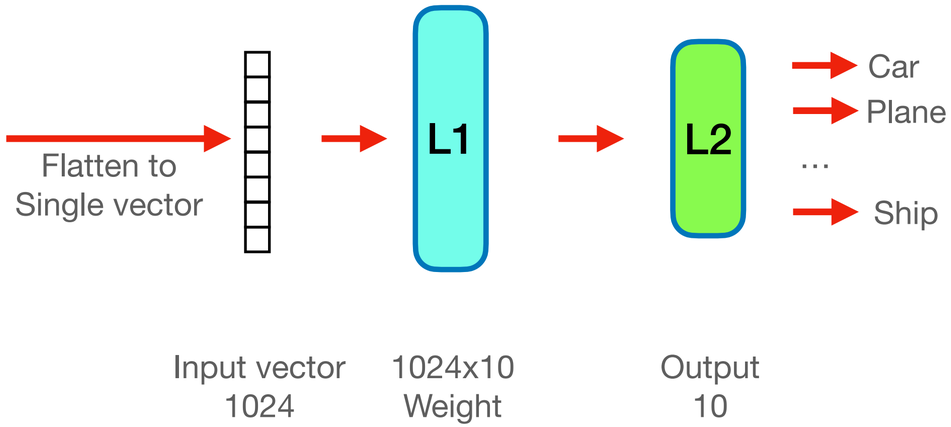
Source: Photo by Dan Gold on Unsplash

Image classification

Fully connected neural network is not efficient for image.

- Spatial information is hard to capture
- Parameter only learn pixel information in specific position
- Number of parameter can get large

32x32 with single color



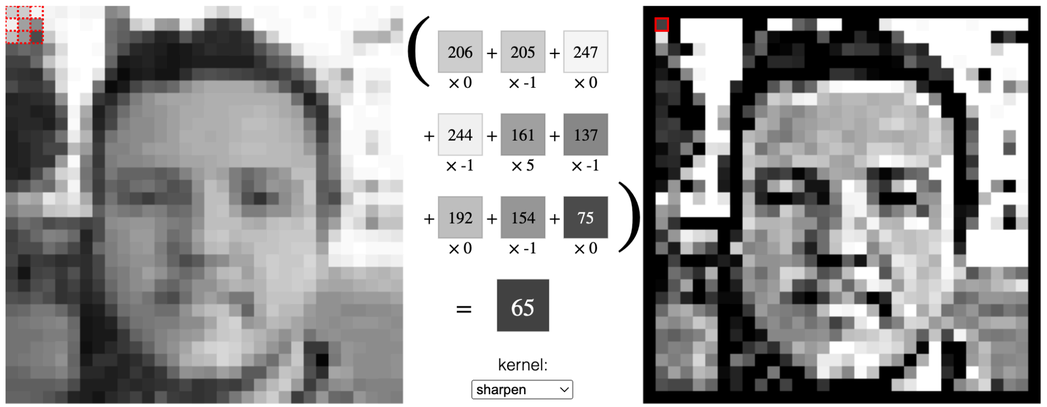
Kernel in image processing

- Kernel (3x3 or 5x5 matrix) is applied to images by sliding
- Based on the kernel, it can detects edges, blue, sharpen images

sharpen

$$\begin{pmatrix} 0 & -1 & 0 \\ -1 & 5 & -1 \\ 0 & -1 & 0 \end{pmatrix}$$

Below, for each 3x3 block of pixels in the image on the left, we multiply each pixel by the corresponding entry of the kernel and then take the sum. That sum becomes a new pixel in the image on the right. Hover over a pixel on either image to see how its value is computed.



input image output image

Source: https://setosa.io/ev/image-kernels/

0	-1	0
-1	5	-1
0	-1	0

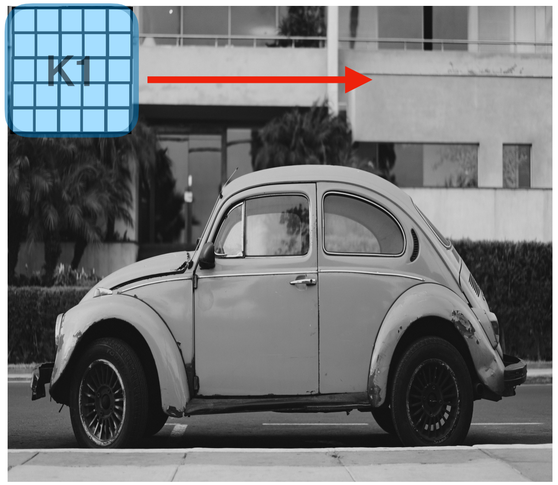
sharpen

3. Convolutional neural network

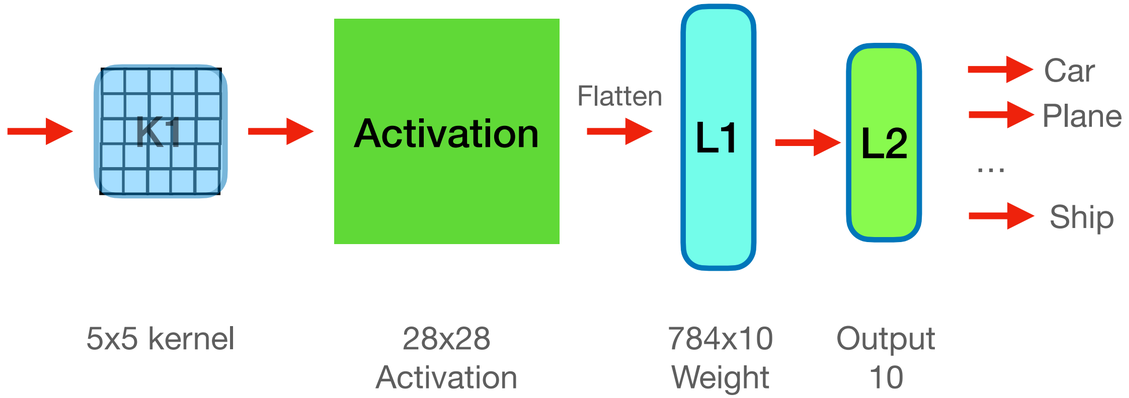
Image classification

Convolutional neural network

- Convolve kernel over the image
- *i.e.* slide the kernel over the image and do the dot product (multiply each element and sum them)
- Keeping the spatial information
- Kernel is reused for all inputs



32x32 with single color



Source: Photo by Dan Gold on Unsplash

Image classification

Convolutional neural network

- Color image, rgb: defined as 3 channels
- Number kernel is always based on the input channel
- i.e. 3 in kernel in this example

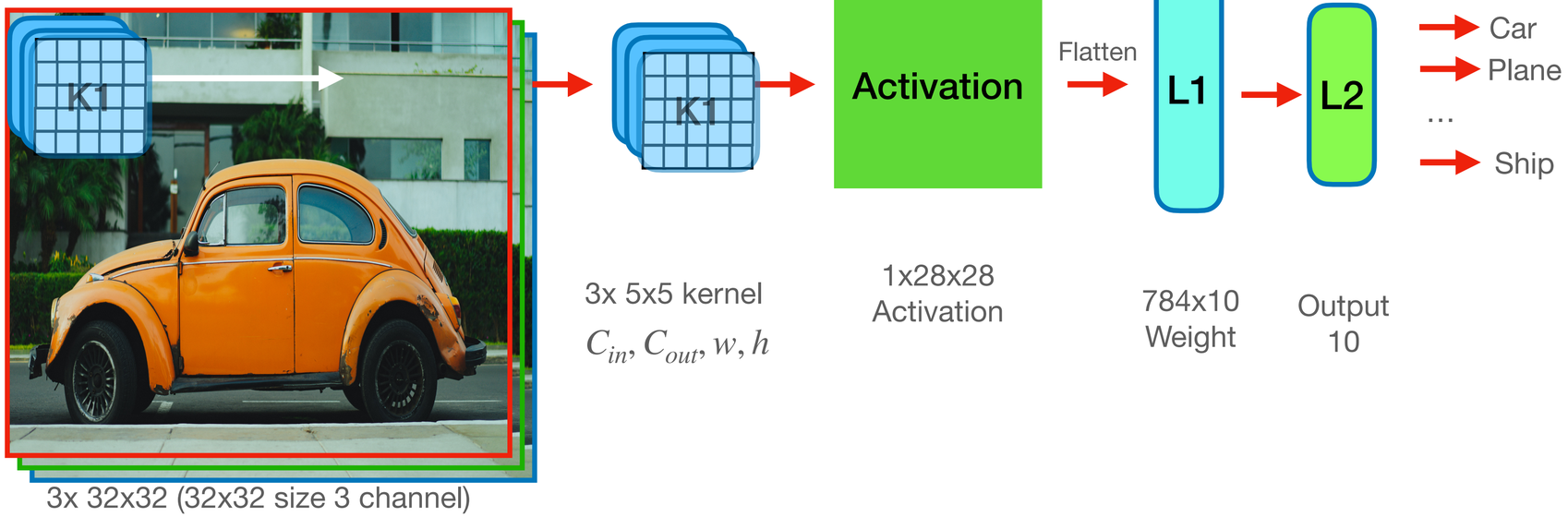
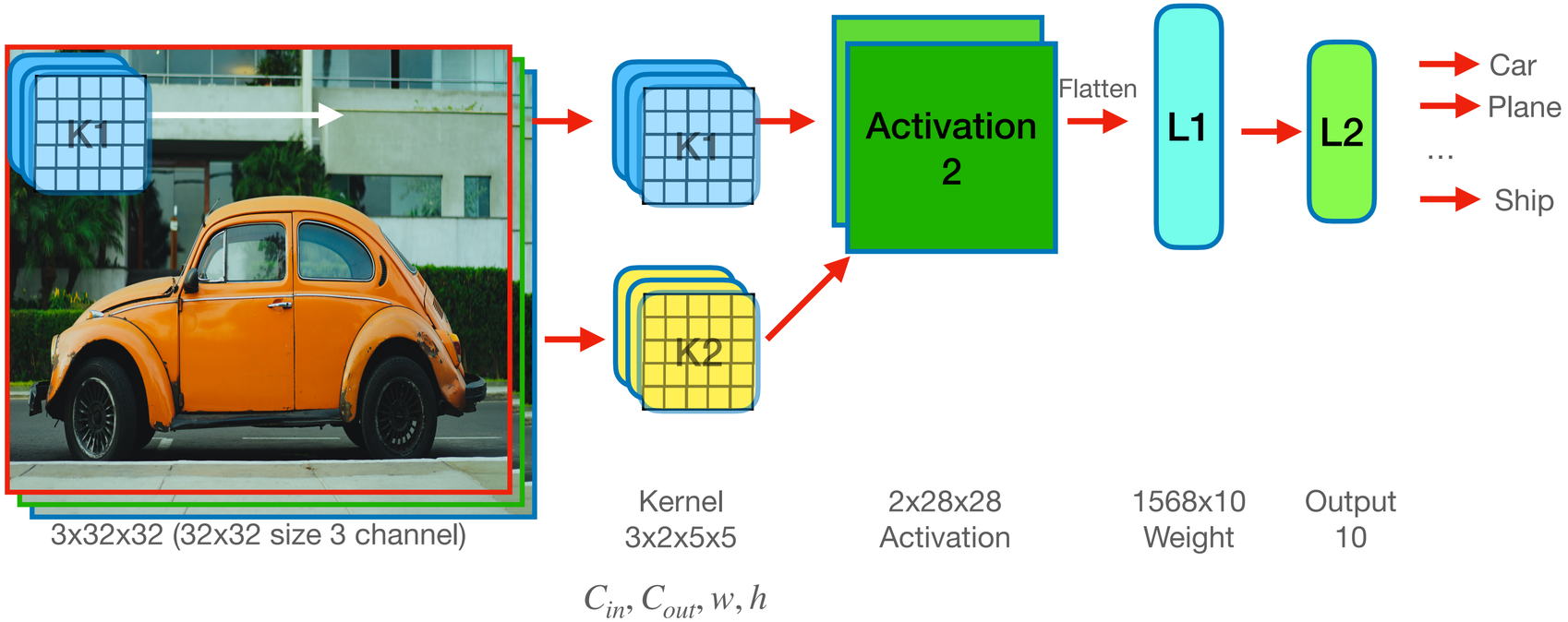


Image classification

Convolutional neural network

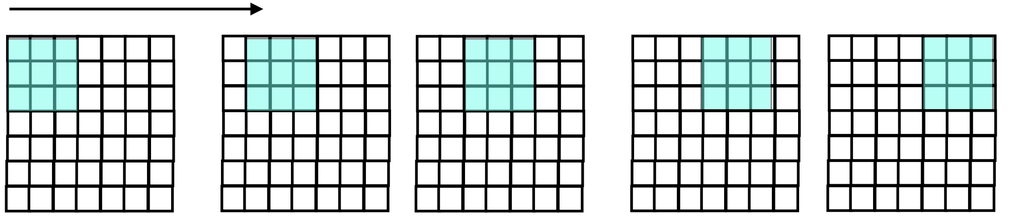
- Multiple kernel can be used



Stride

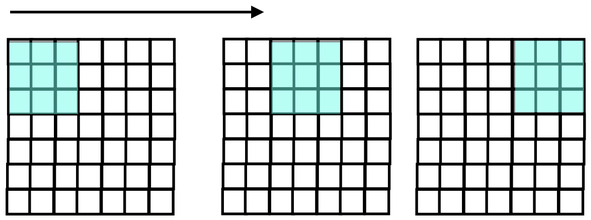
- Define how many steps to move
- Stride 3? Won't fit
- Output = $\frac{(N-F)}{S}+1$
- N: input size (assume same height&width)
- F: kernel size
- S: stride

Slide 1
3x3 kernel moves 1 step, output dim is 5x5



7x7 input

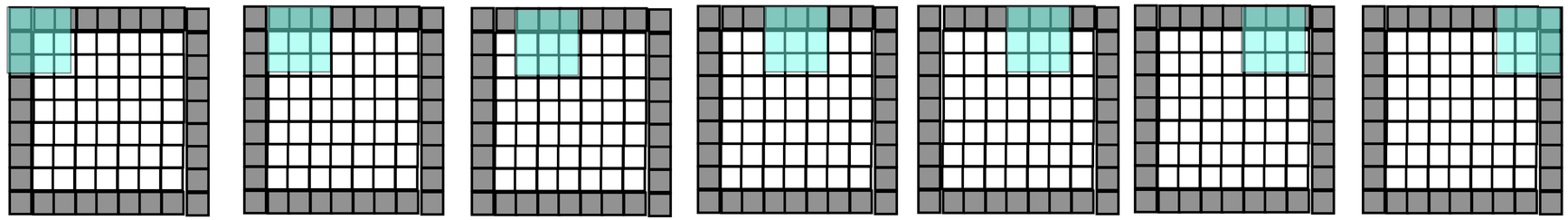
Slide 2
3x3 kernel moves 2 step2



Padding

- To preserve the same dimension for output
- Add paddings (0) to the input
- Output :
  - $\frac{(N + 2P - F)}{S} + 1$
- N: input size (assume same height&width)
- F: kernel size
- S: stride
- P: padding
- To preserve the size, add padding size $P = (F - 1)/2$
  - When F=3 -> P=1, F=5 -> P=2

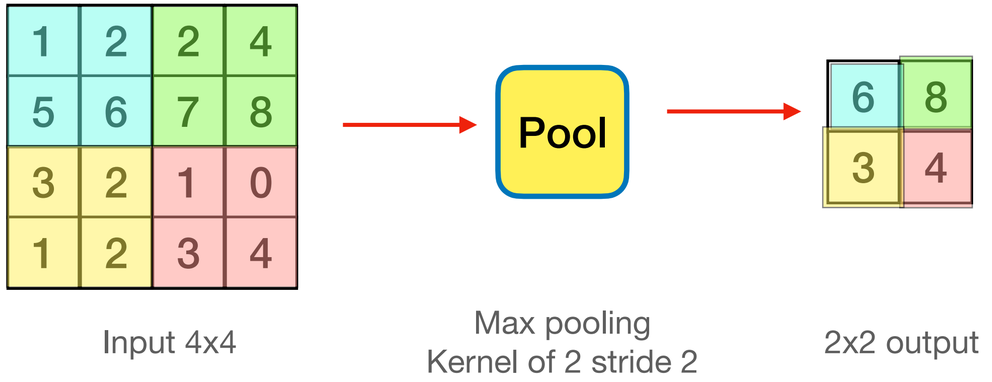
Slide 1, padding 1
3x3 kernel moves 1 step, output dim is 7x7

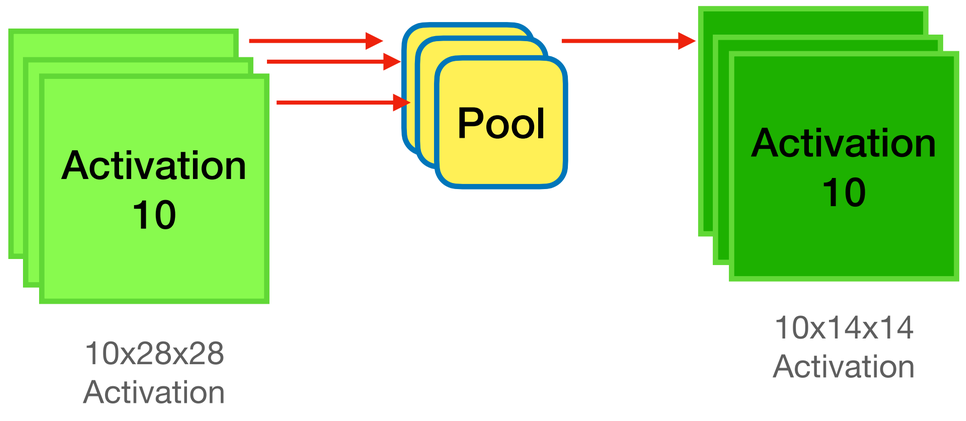


7x7 input
Gray area is zero padding

Pooling

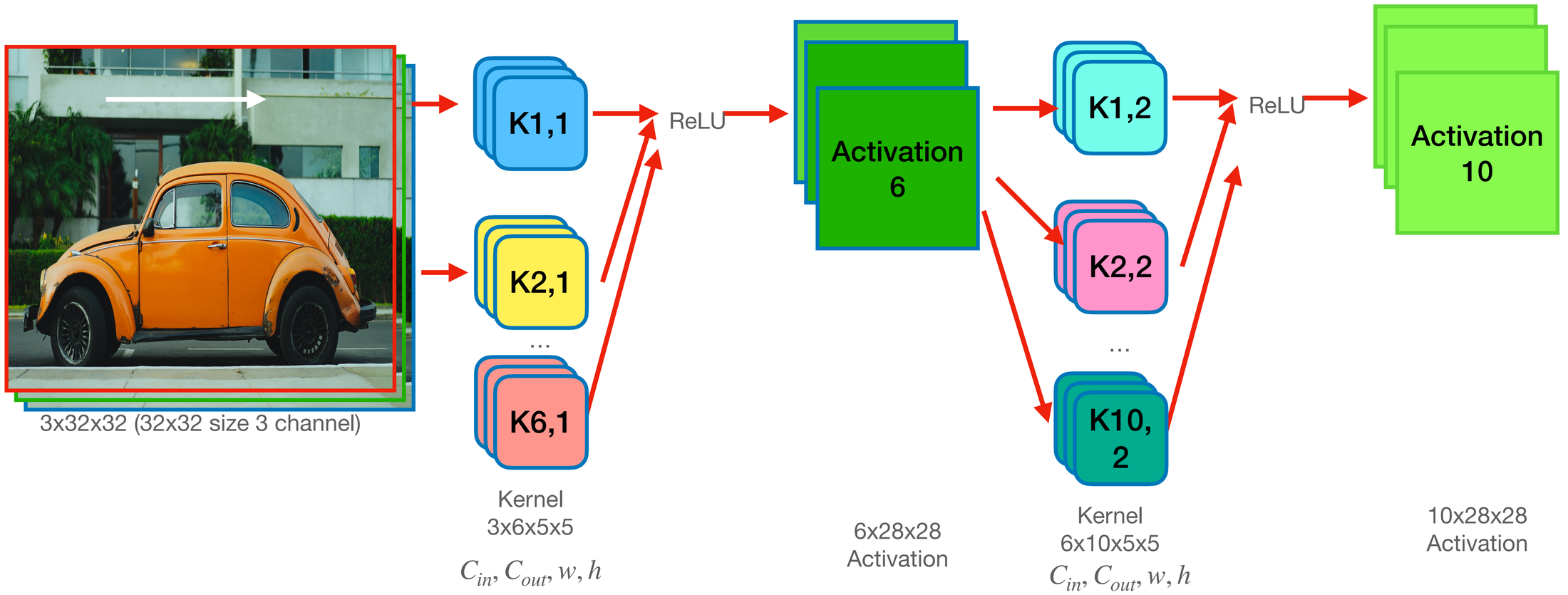
- Reduce the activation size
- Applied to each activation layers independently
- Downsample the input
- Max, average pool are used
- No learnable parameters





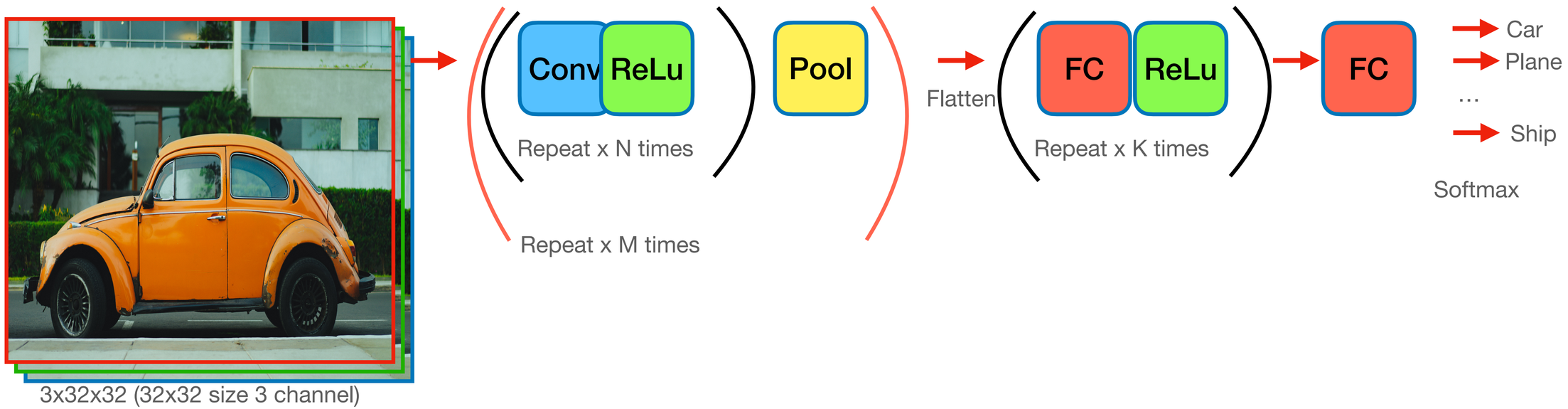
CNN structure

- Multiple Conv kernel layer with non-linear layer (ReLU)



CNN structure

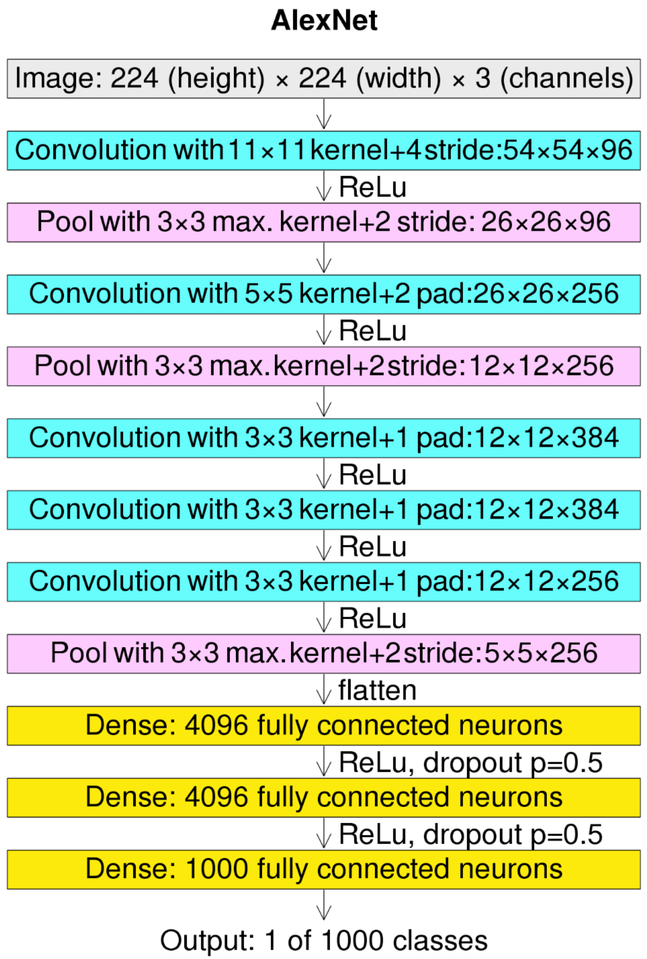
- Repeats with cons, relu, and pooling layer, and add fully connected layer at the end



4. CNN architectures

Alexnet

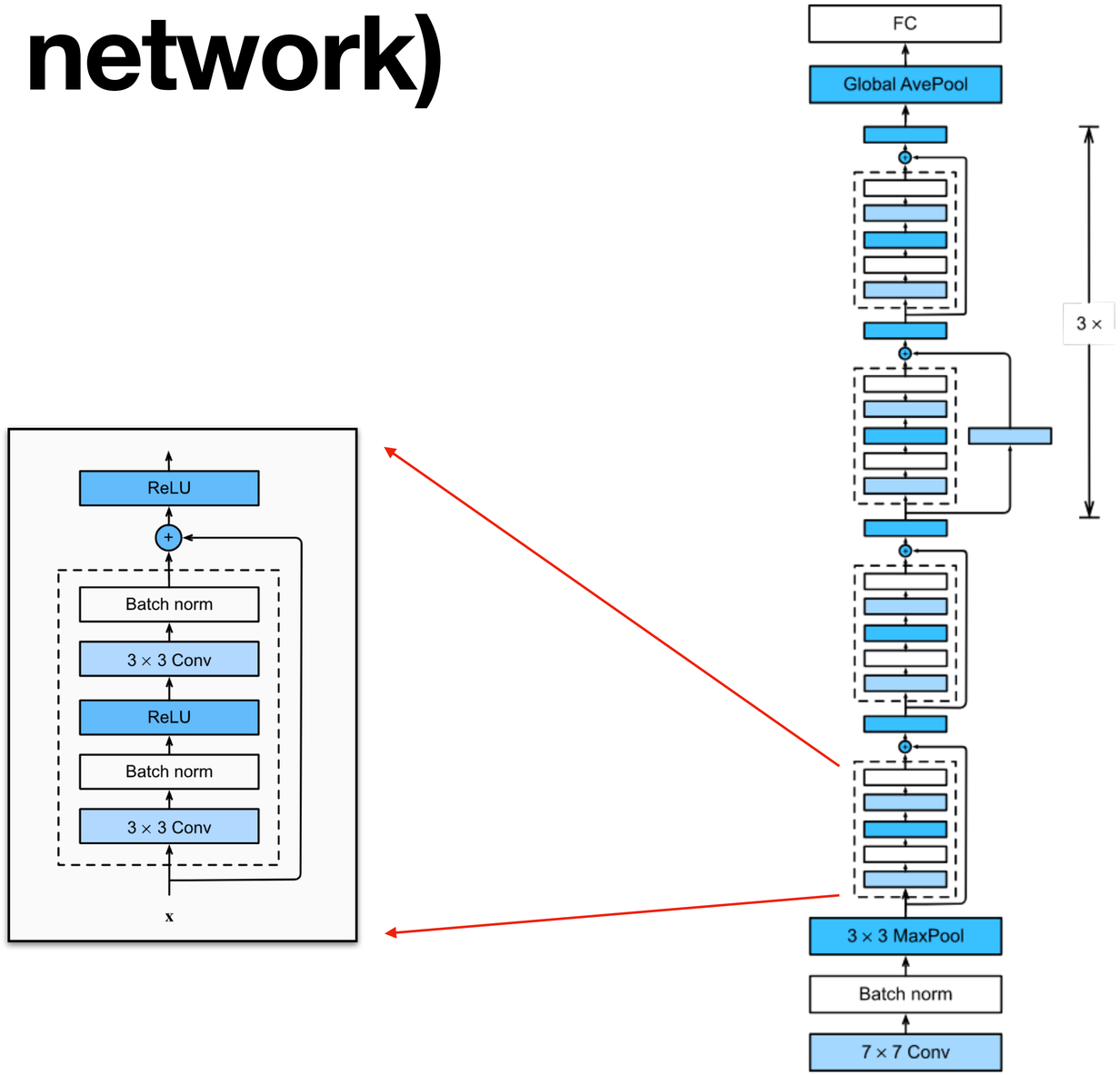
- CONV1
- MAX POOL1
- NORM1
- CONV1
- MAX POOL2
- NORM2
- CONV3
- CONV4
- CONV5
- MAX POOL3
- FC6
- FC7
- FC8



Source: https://en.wikipedia.org/wiki/AlexNet

Resnet (Residual network)

- Accomplished very deep network using skip connection
- Original Resnet is 152 layers
- Showing a smaller example of Resnet-18

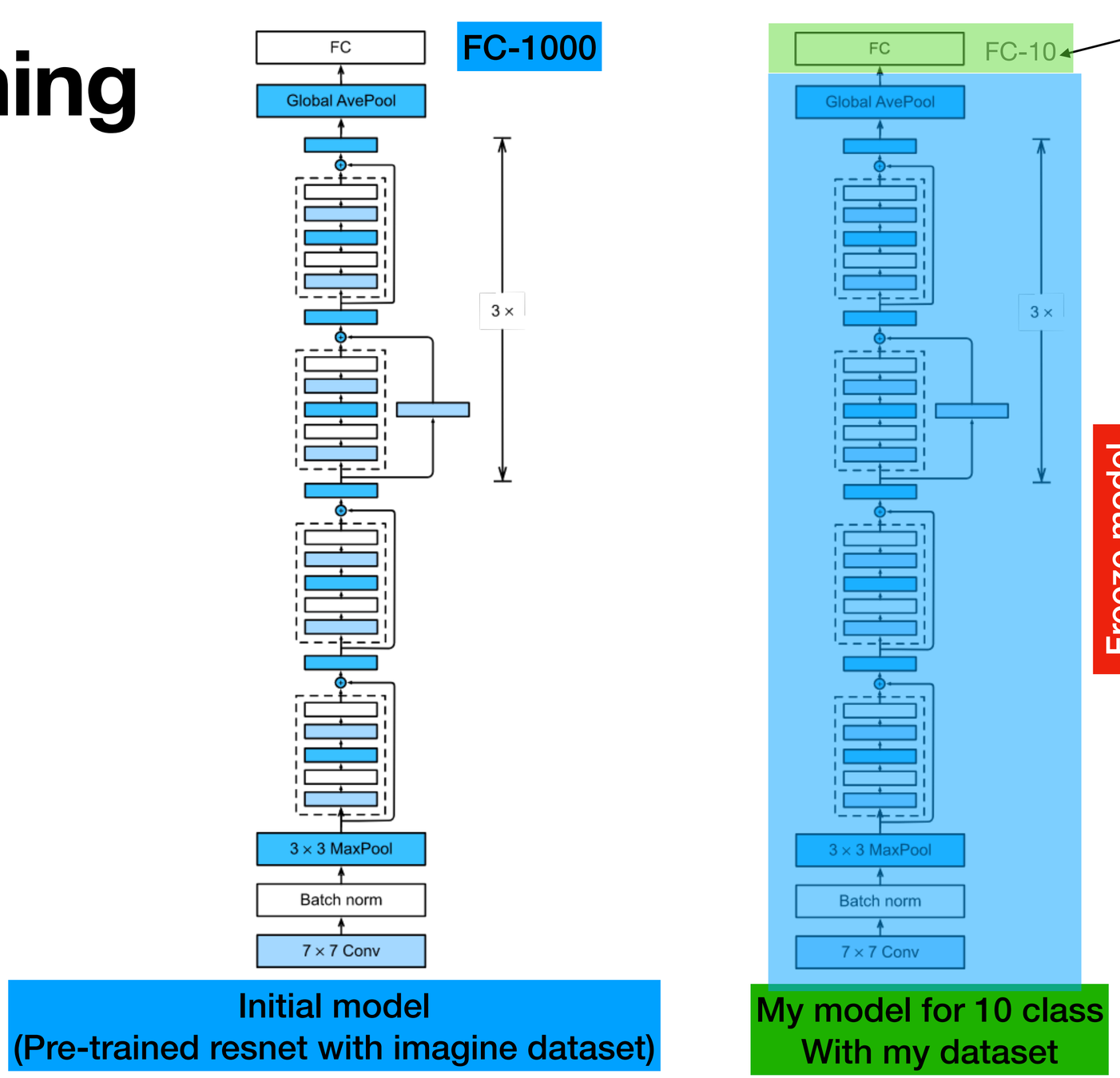


Source: https://d2l.ai/chapter_convolutional-modern/resnet.html

5. Transfer learning

Transfer learning

- Pre-trained model:a model with large dataset (Imagenet)
- Keep the Conv layers as a backbone network
- Replace FC(s) to number classes for the model
- Pre-trained backbone network is used everywhere



Credits

The following materials are referenced for this slide.

- Sample CNN code from Pytorch tutorial
- Full Stack Deep Learning
- Deep Learning for Computer Vision