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POST GRADUATE PROGRAM IN GENERATIVE AI AND ML

Deep Learning and Neural Network Architectures

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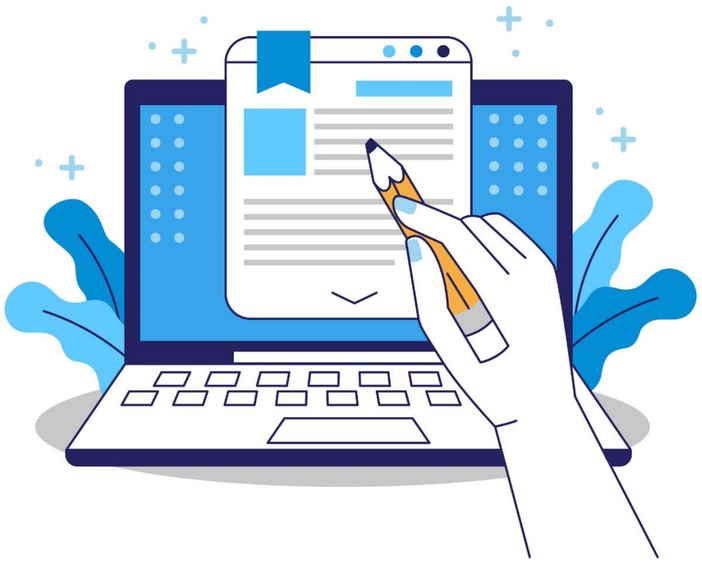
Convolutional Neural Networks - I

Topics

- Introduction to CNN
- Image Representation
- Convolutional Operations
- Pooling: Max and Average Pooling
- Global Pooling
- CNN: Layer and Architecture
- Visualizing Feature Maps and Filters
- Normalization and Image Augmentation



Learning Objectives

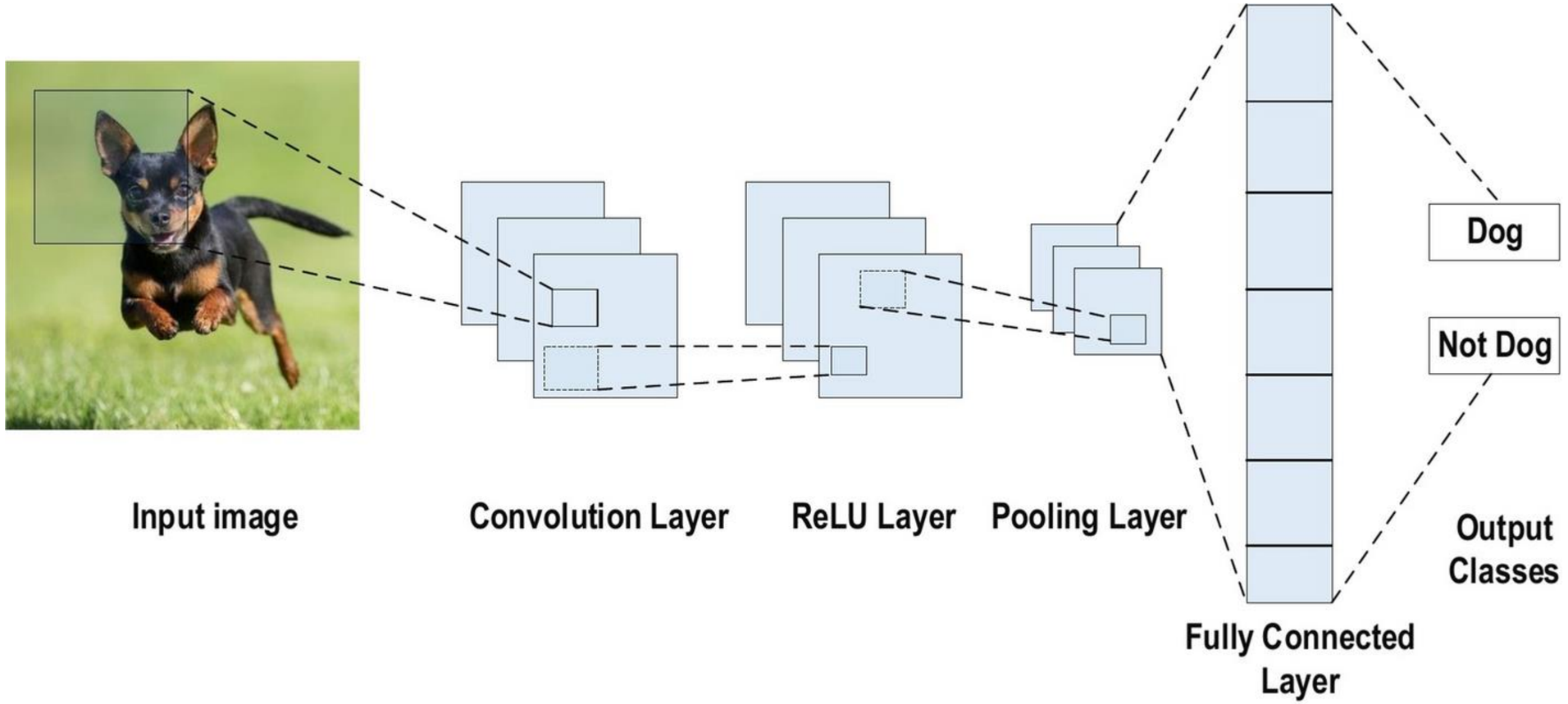
By the end of this lesson, you will be able to:

- Understand the basics and purpose of CNNs.
- Visualize how images are represented as input to CNNs.
- Explore convolution and pooling operations in CNNs.
- Identify key layers and architecture of a CNN model.
- Visualize feature maps and apply normalization and augmentation.

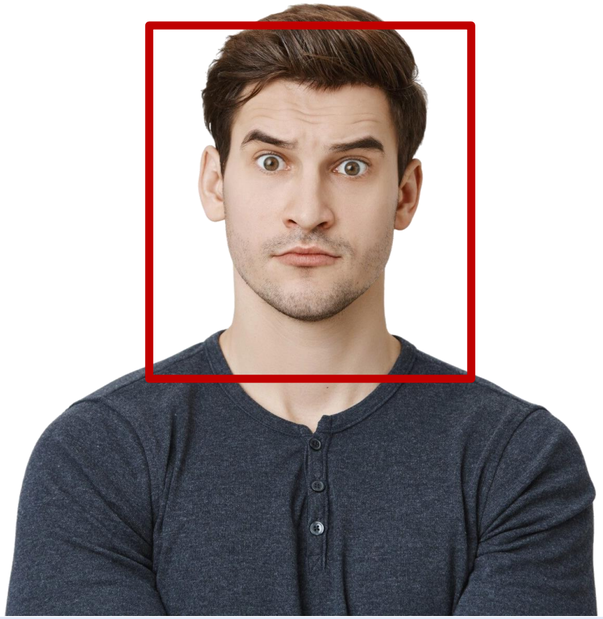
Introduction to CNNs

What are CNNs?

CNNs are deep learning models designed to process pixel data, especially images.



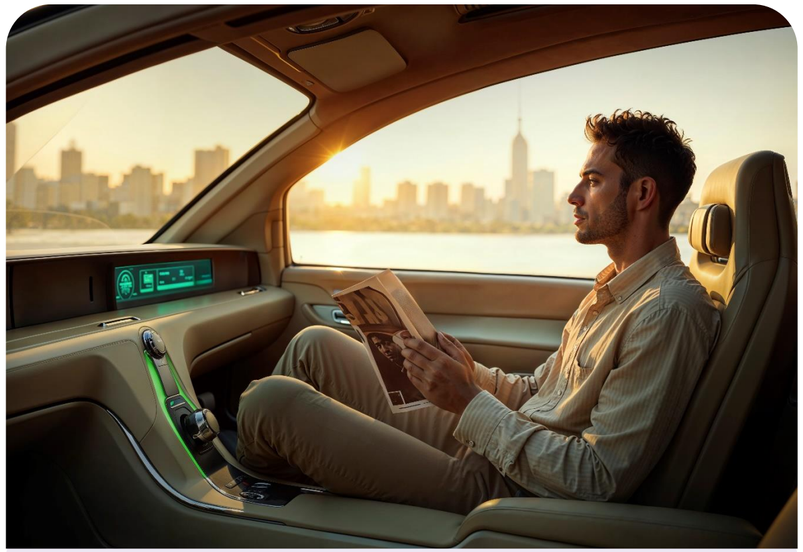
Applications of CNNs



Face Recognition

Medical Imaging

Applications of CNNs (Contd.)

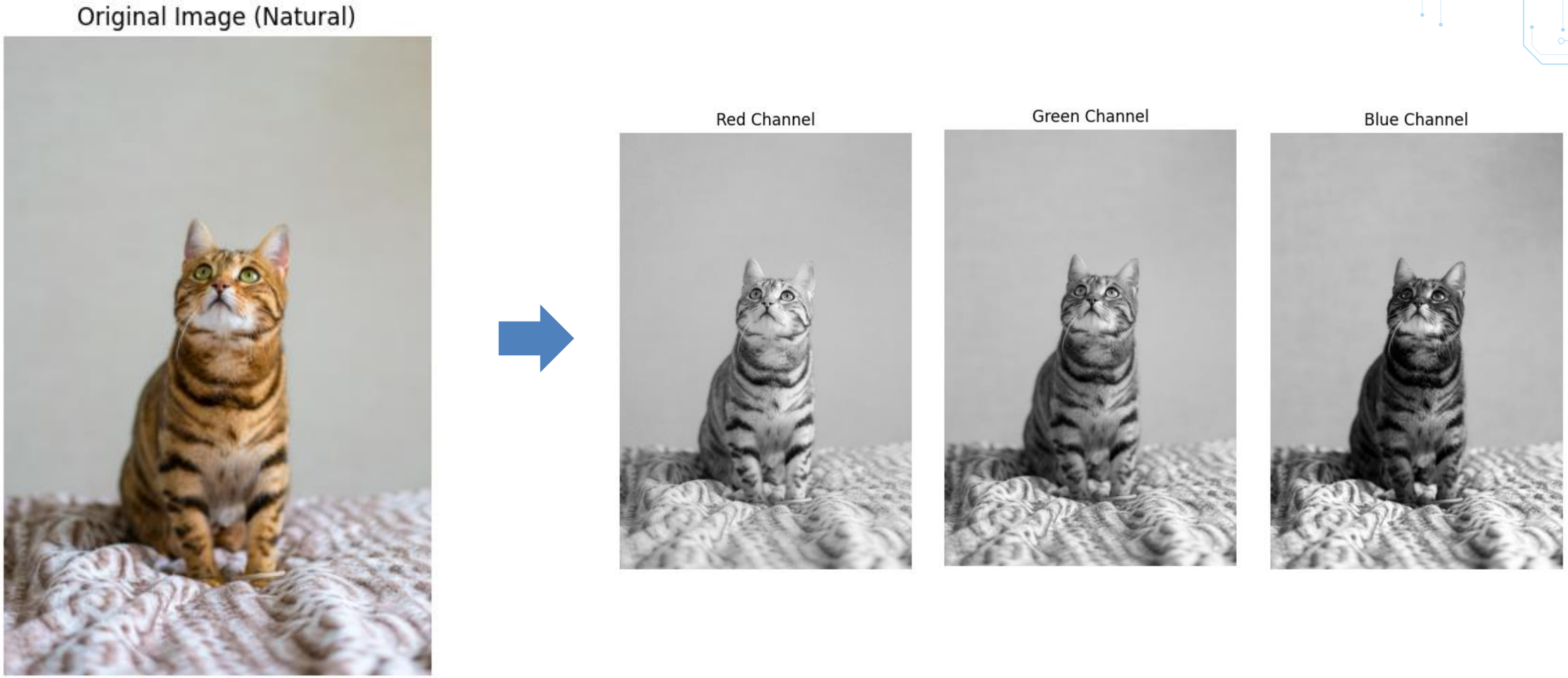


Self-Driving

Object Detection

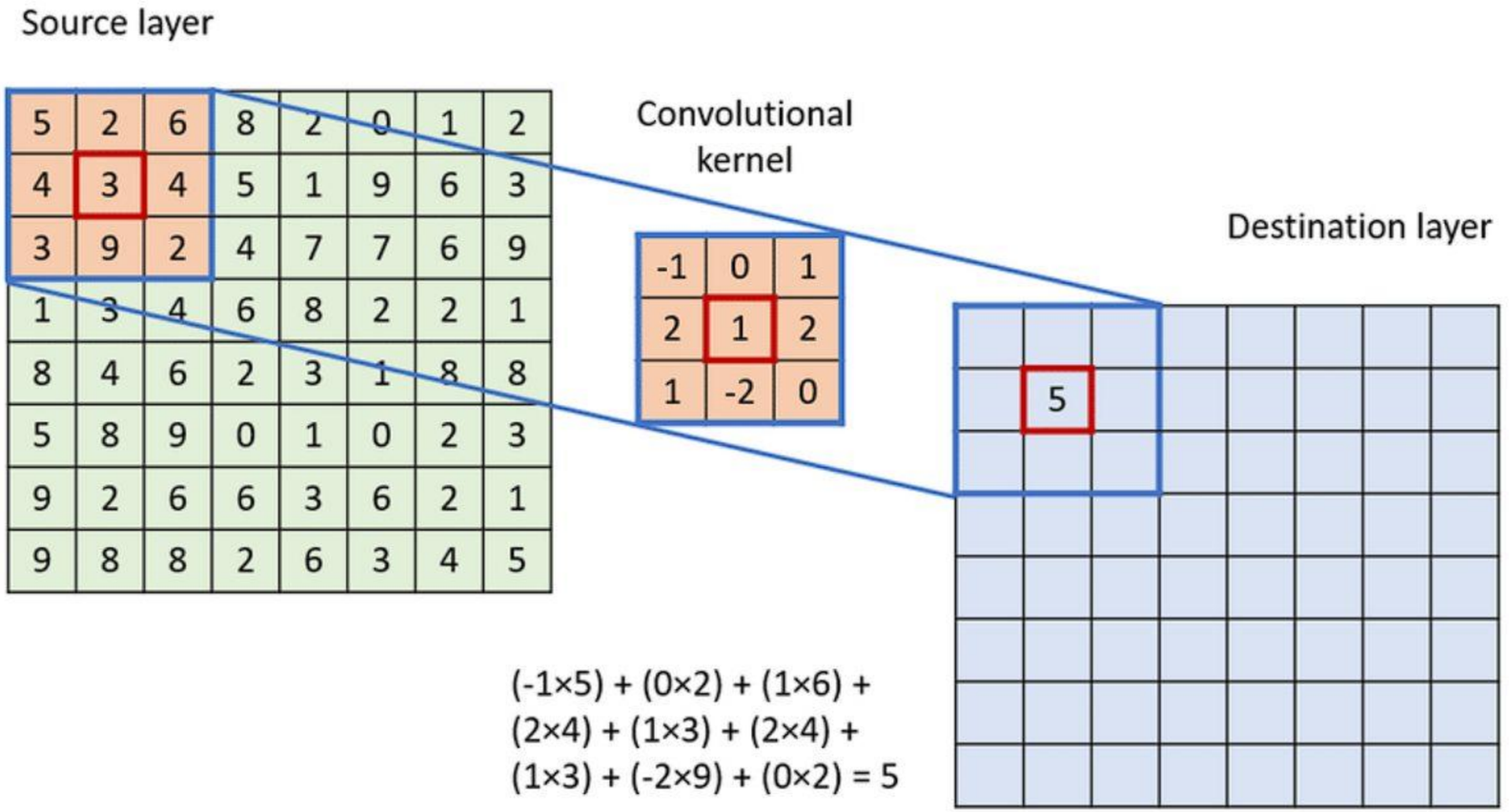
Image Representation

How CNNs View Images?



Convolutional Operations

Convolutional Operation



Kernel

A kernel is a small 2D matrix whose contents are based upon the operations to be performed.

0	0	0
0	1	0
0	0	0

Original

0.06	0.12	0.06
0.12	0.25	0.12
0.06	0.12	0.06

Gaussian

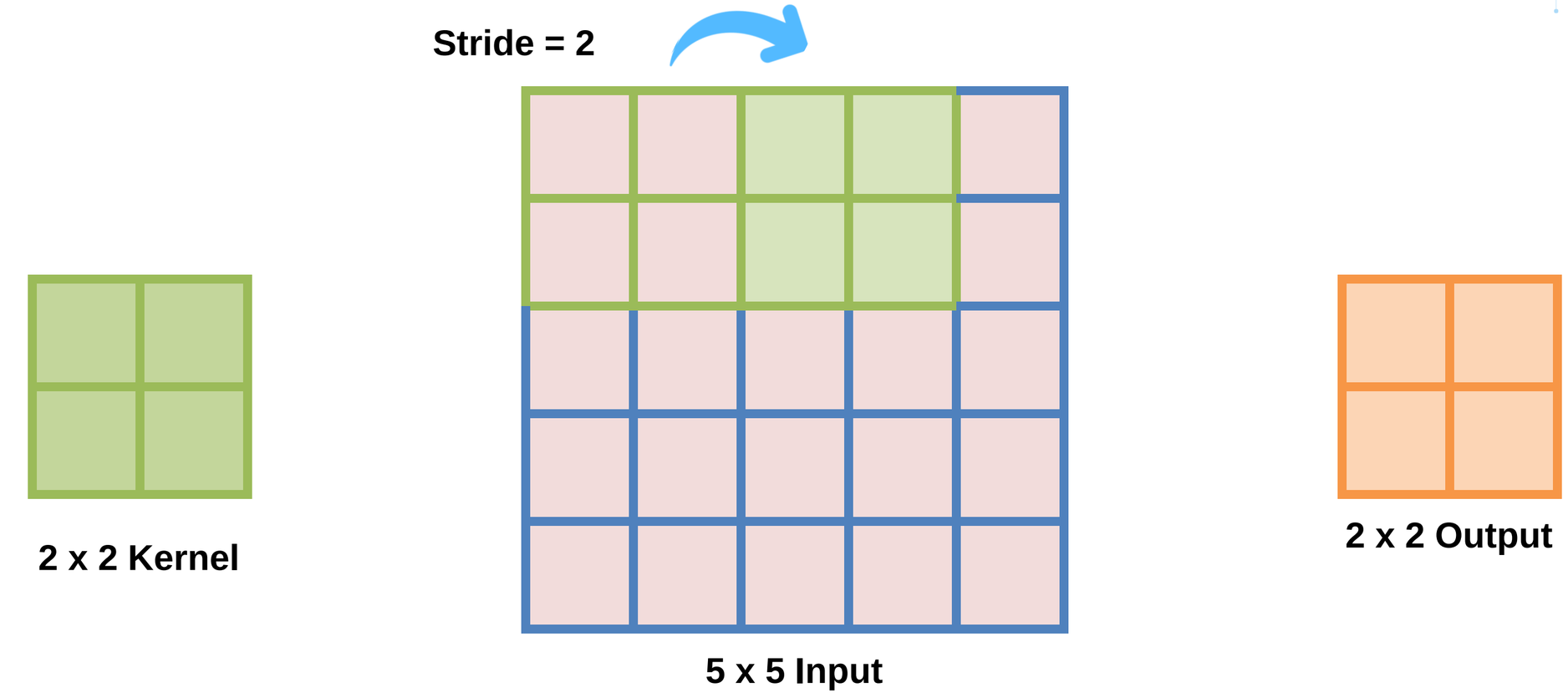
0	-1	0
-1	5	-1
0	-1	0

Sharpen

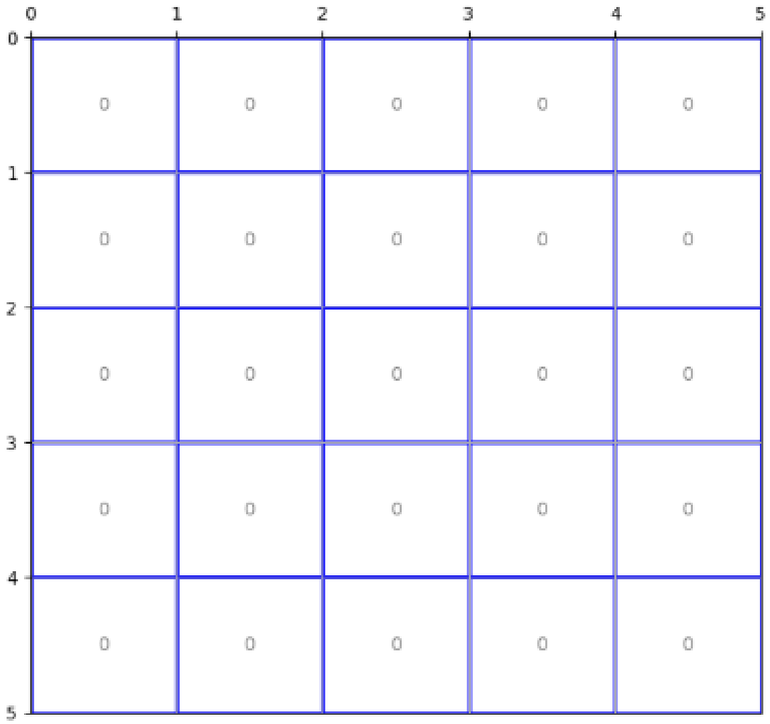
-1	-1	-1
-1	8	-1
-1	-1	-1

Edge

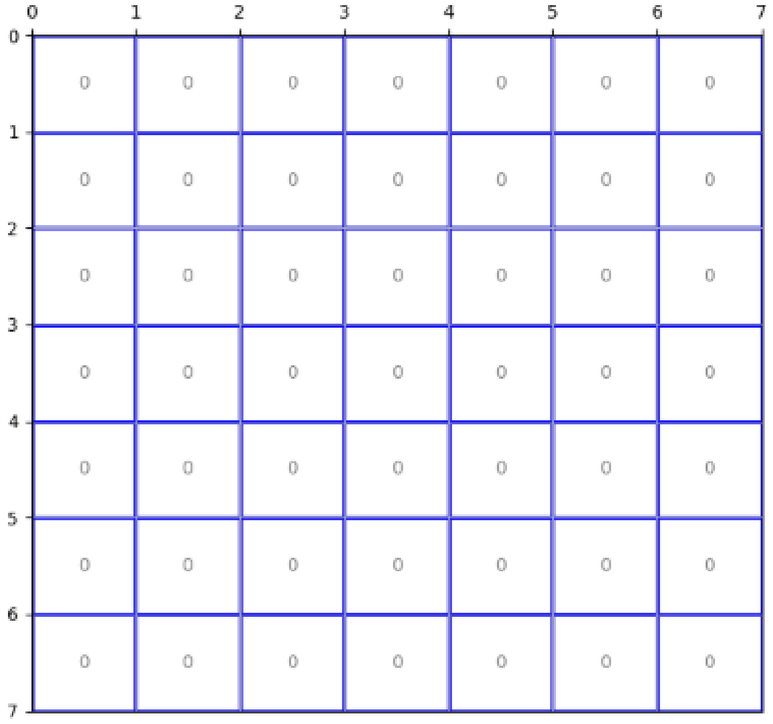
How a Kernel Moves Over an Image?



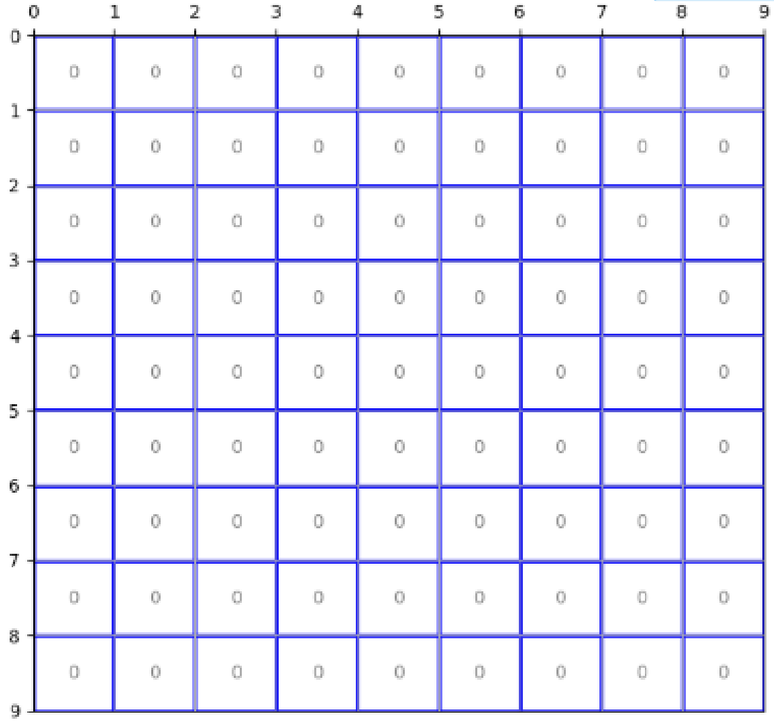
Padding



Original (Padding = 0)

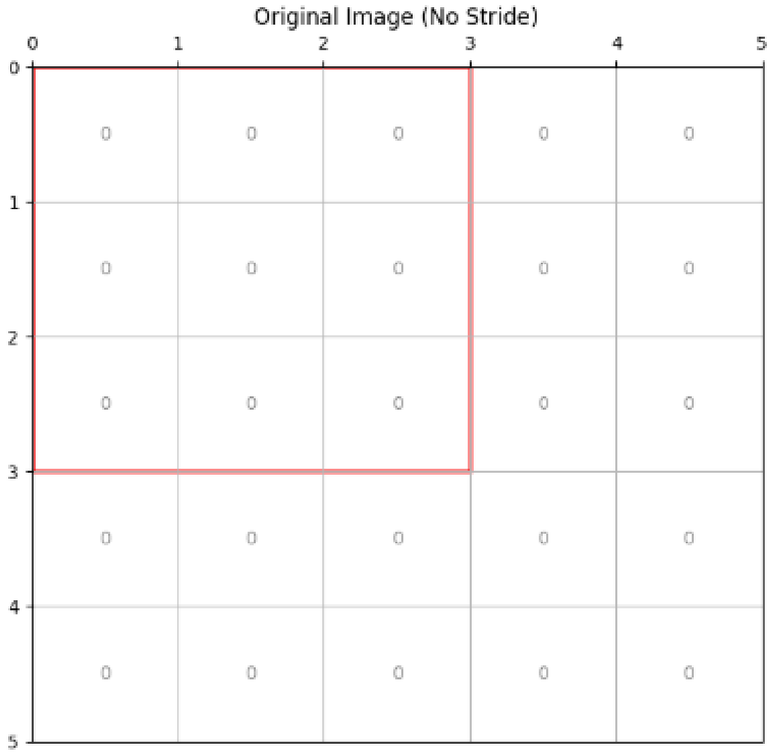


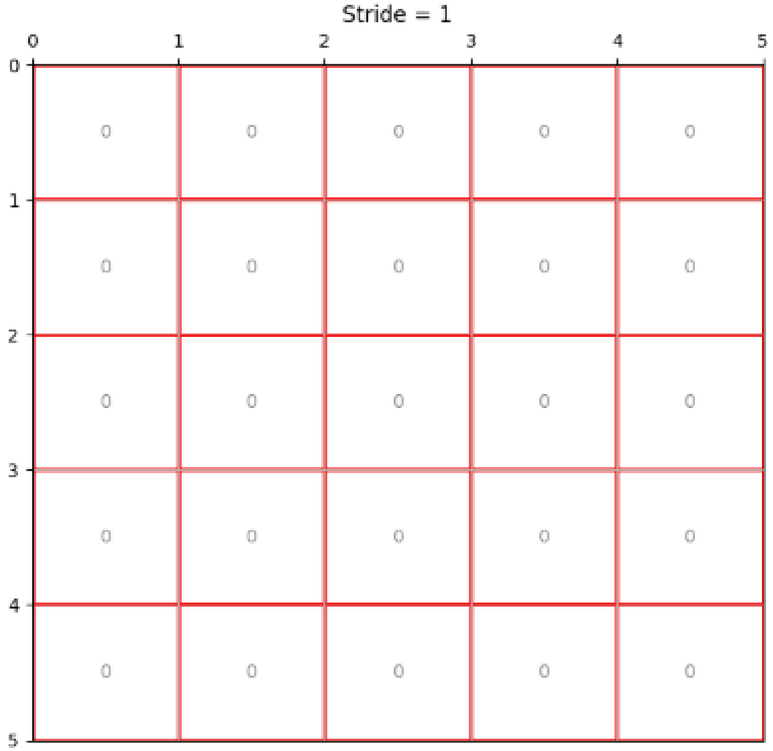
Padding = 1

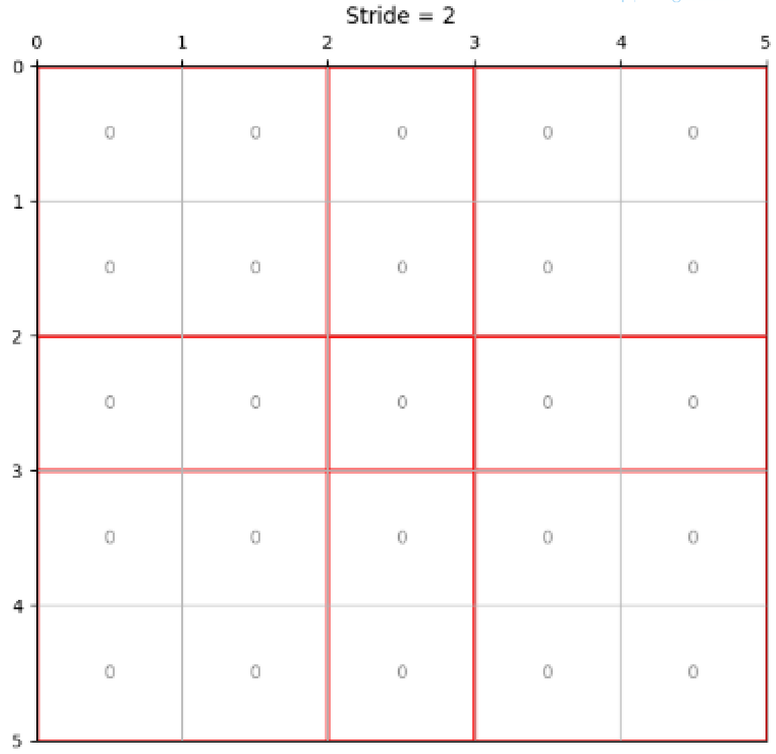


Padding = 2

Stride



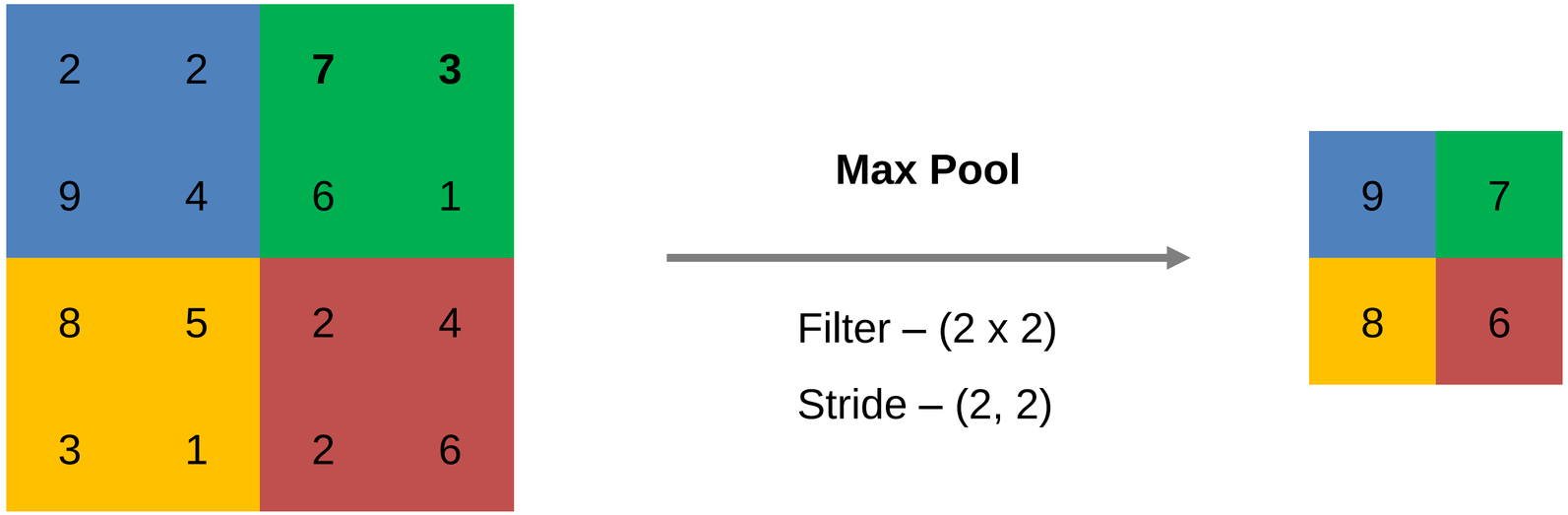




Pooling

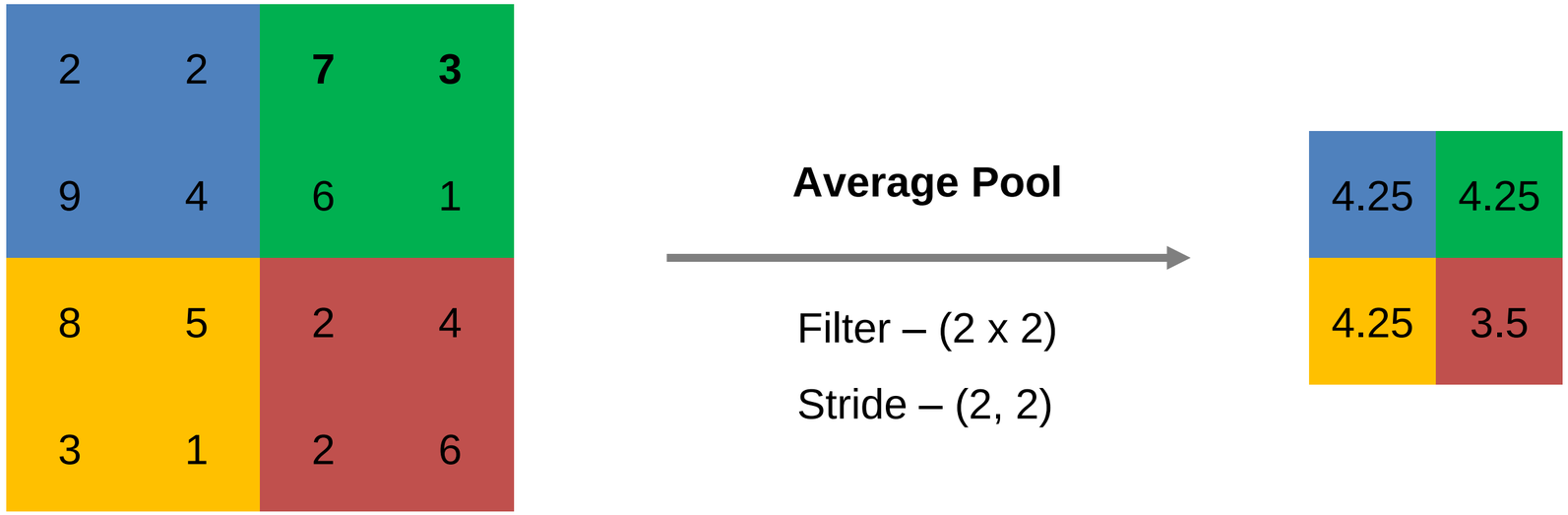
Max Pooling

Max pooling is a pooling operation that selects the maximum element from the region of the feature map covered by the filter.



Average Pooling

Average pooling computes the average of the elements present in the region of the feature map covered by the filter.



Global Pooling

1	2	**3**
4	5	6
7	8	9

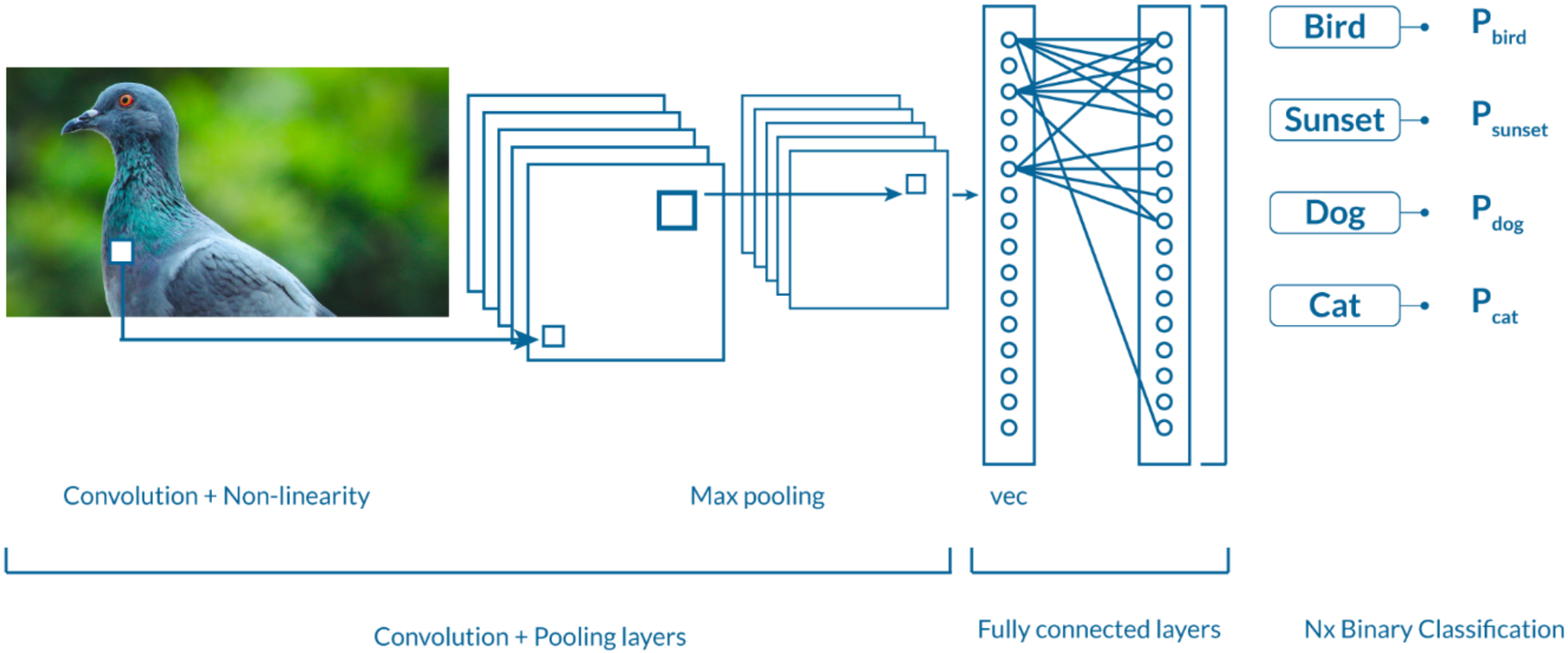
Global Max Pooling = 9

1	2	**3**
4	5	6
7	8	9

Global Average Pooling = 5

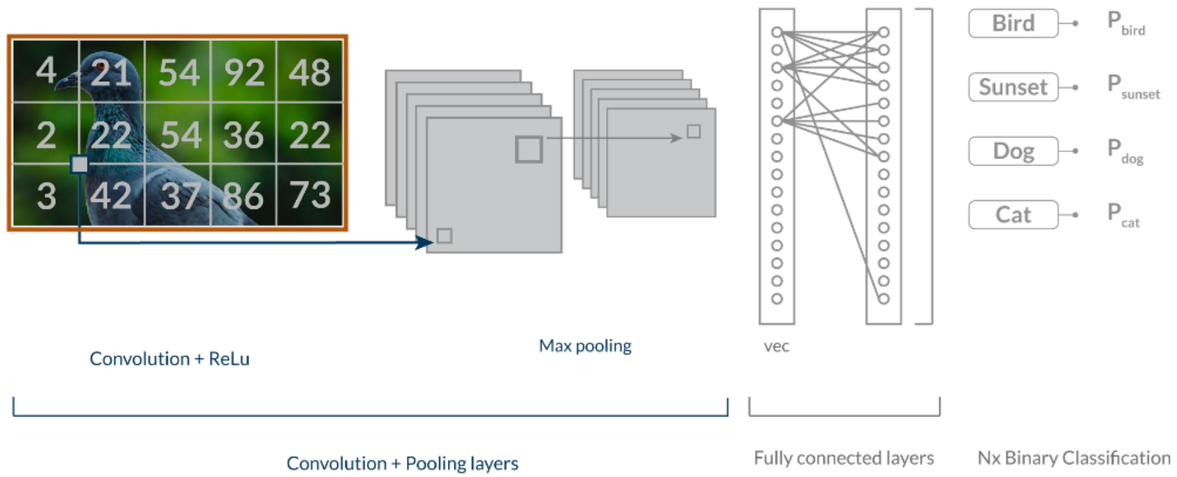
CNN: Layer and Architecture

Layers in CNN

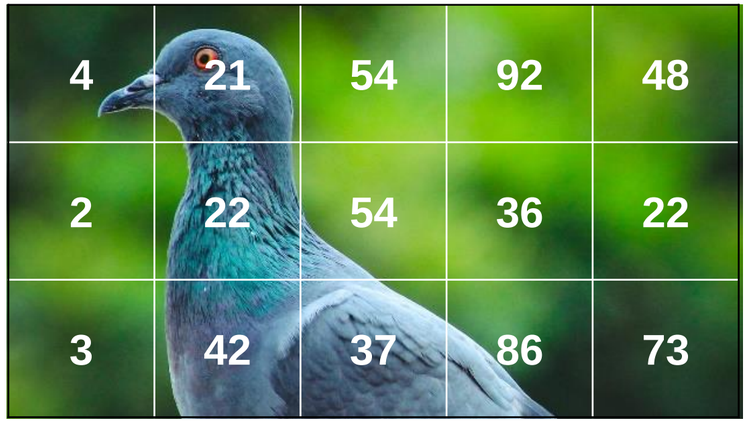


Convolutional Layer

- First layer of CNN
- Stores the pixelated values of the image into an array
- Used for extracting the features of the image and reducing its dimensionality



Convolutional Layer (Contd.)



4	21	54	92	48
2	22	54	36	22
3	42	37	86	73

*

0	-1
1	1

Filter/Feature detector

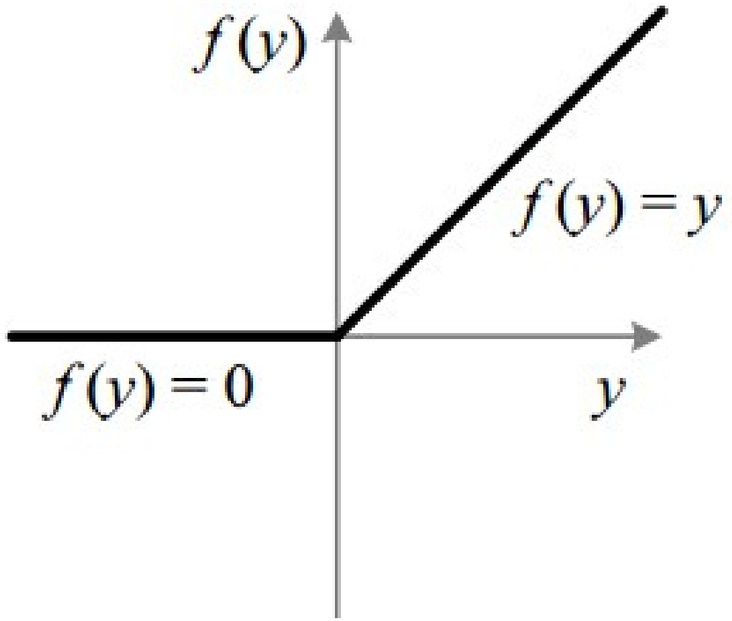
3	22	-2	10
23	25	87	139

- Extracted features from the image
- Dimension reduced

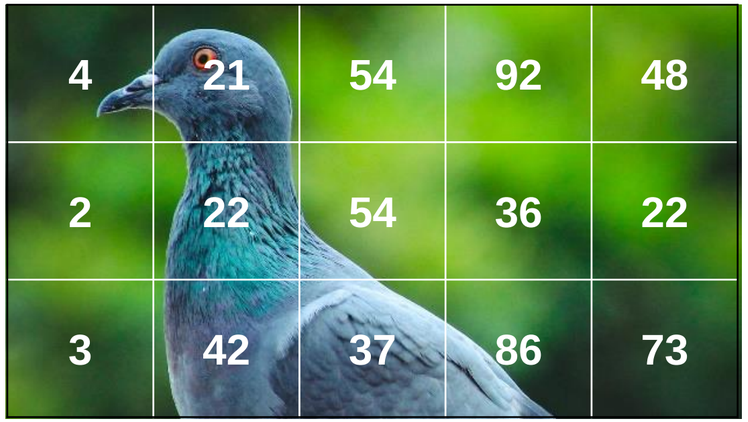
Activation Function: ReLu

“Converts negative values into zero”

- ReLU is a half rectifier
  - f(y) = 0 when y < 0
  - f(y) = y when y > = 0
- Range of ReLU : [0 to infinity]



Activation Function: ReLu (Contd.)



3	22	-2	10
23	25	87	139

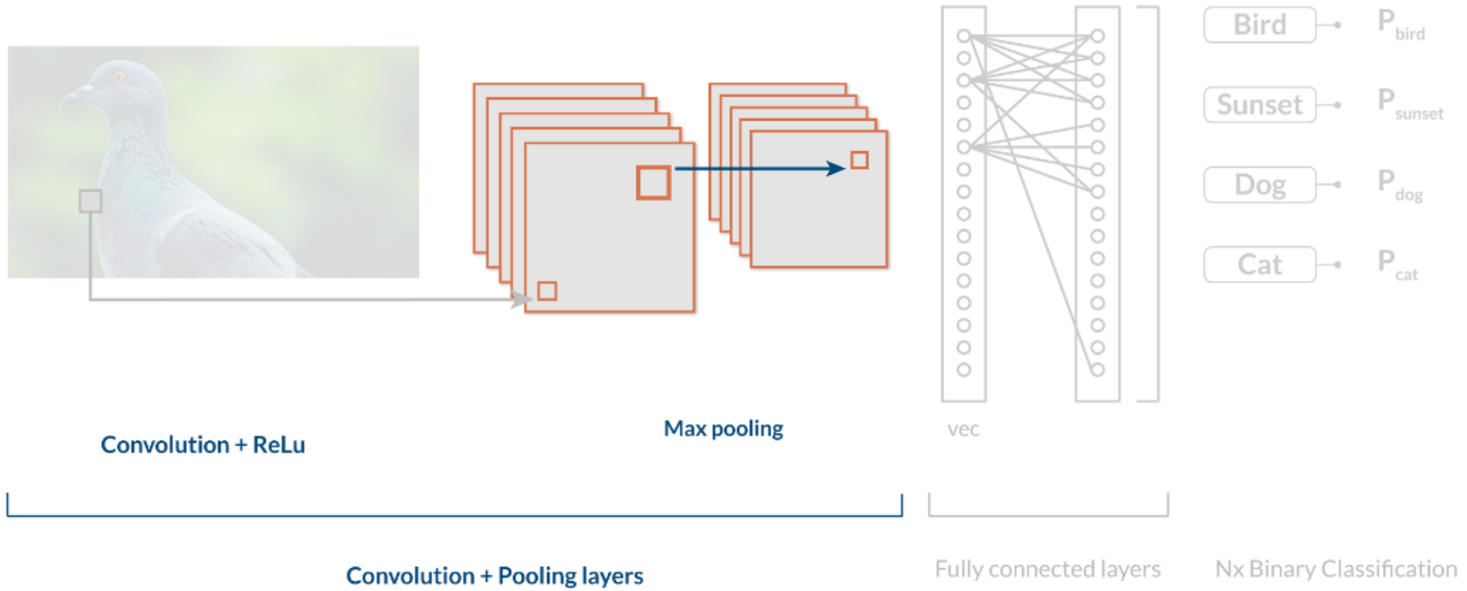
Applying ReLu layer

3	22	0	10
23	25	87	139

After removing the negative values

Pooling Layer

- Used to reduce dimensionality
- Helps to control overfitting
- Filters of size 2x2 are commonly used in it



Pooling Layer (Contd.)

3	22	0	10
23	25	87	139

2 * 2 with stride = 1

Max Pooling

3	22	0	10
23	25	87	139

25			

Amount of movement between applications of the filter to the input image is referred as stride.

3	22	0	10
23	25	87	139

25	87		

3	22	0	10
23	25	87	139

25	87	139	

3	22	0	10
23	25	87	139

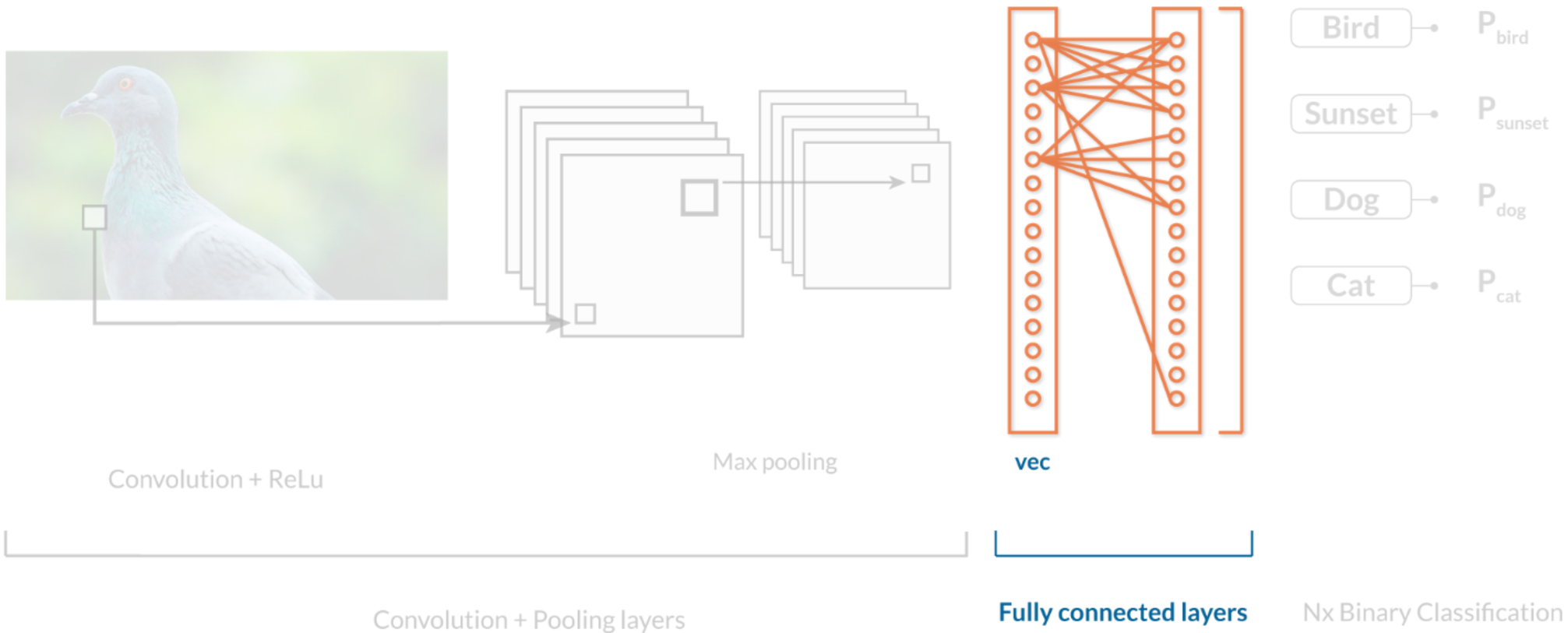
25	87	139	139

Flatten the Data

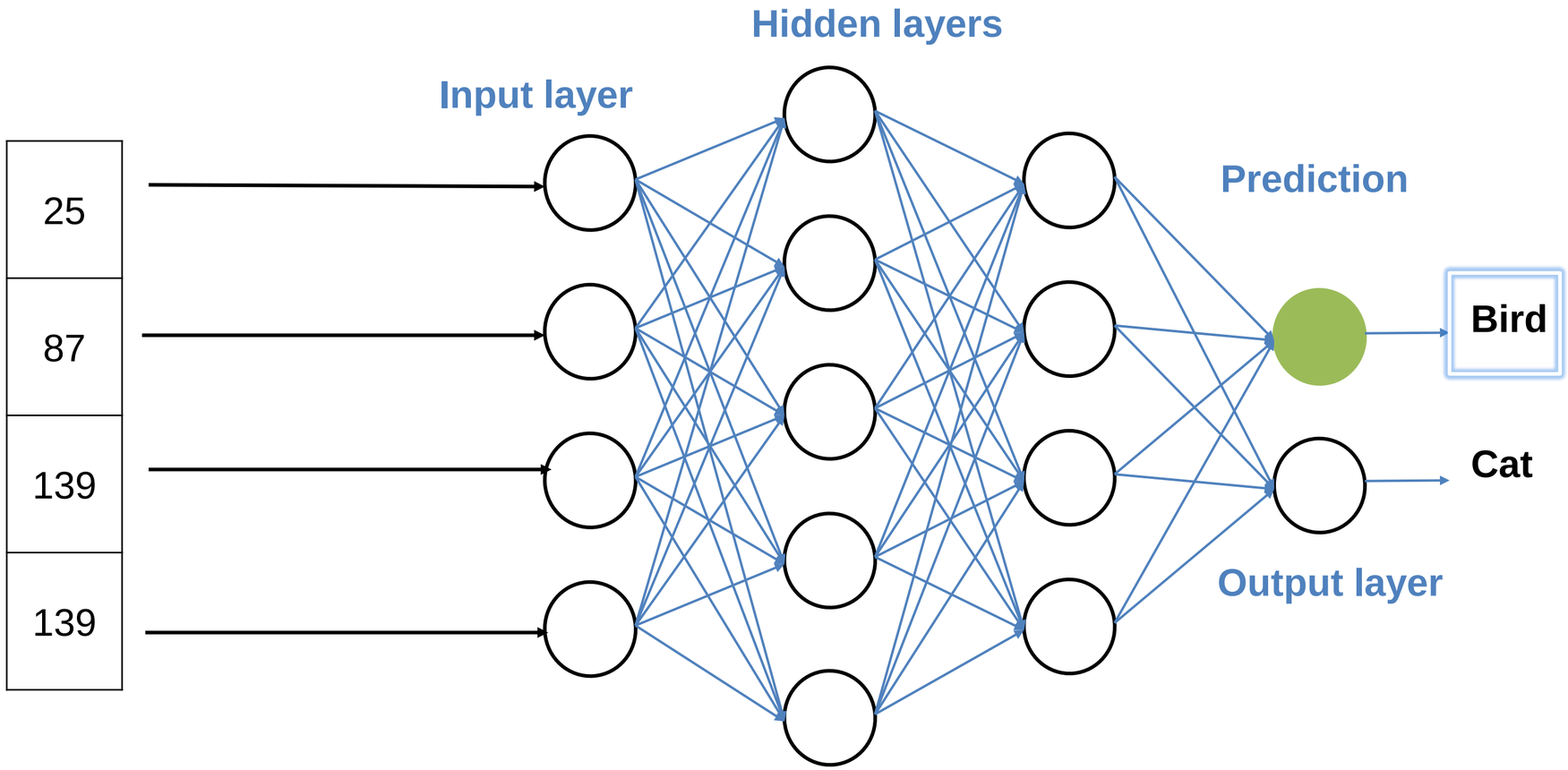
“Converting the Pooled feature map into an array is known as data flattening”

Fully Connected Layer

"Combines all the features together to create a final model"



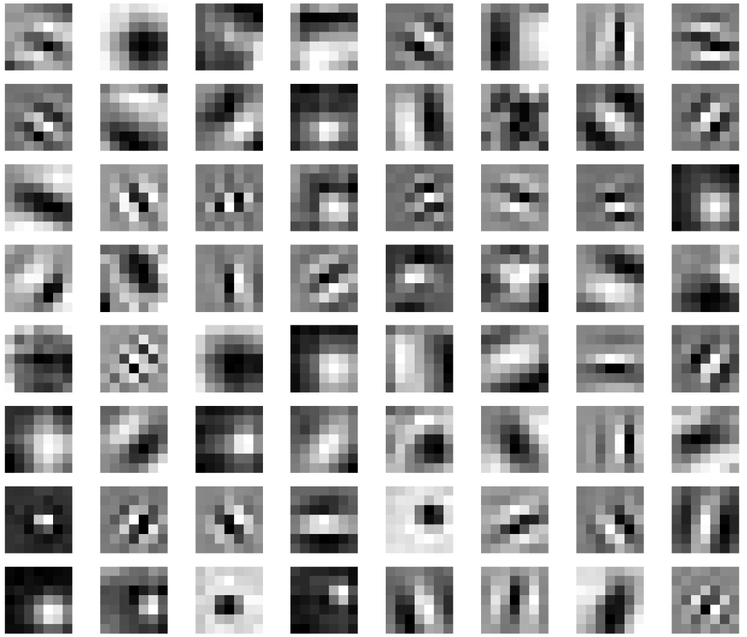
Fully Connected Layer



Visualizing Feature Maps and Filters

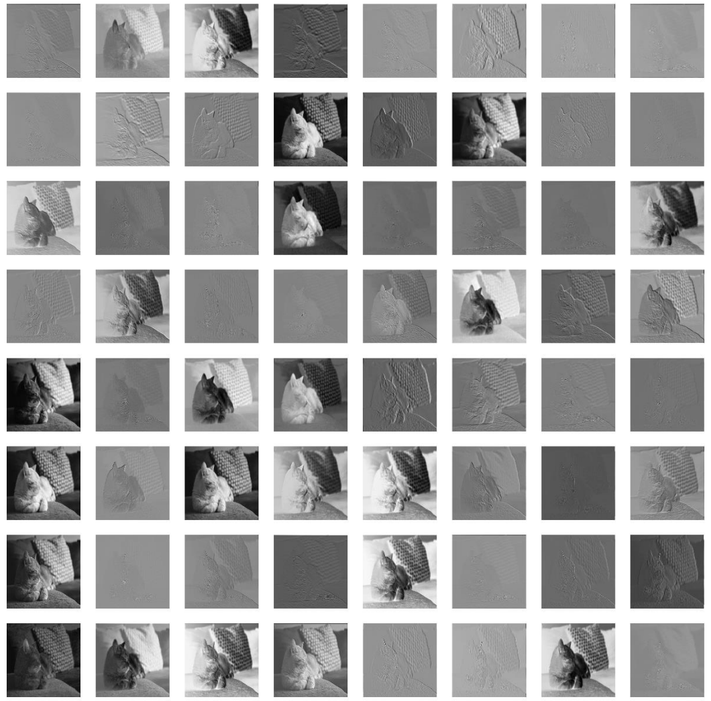
Filters

First convolutional layer filter of the ResNet-50 neural network model



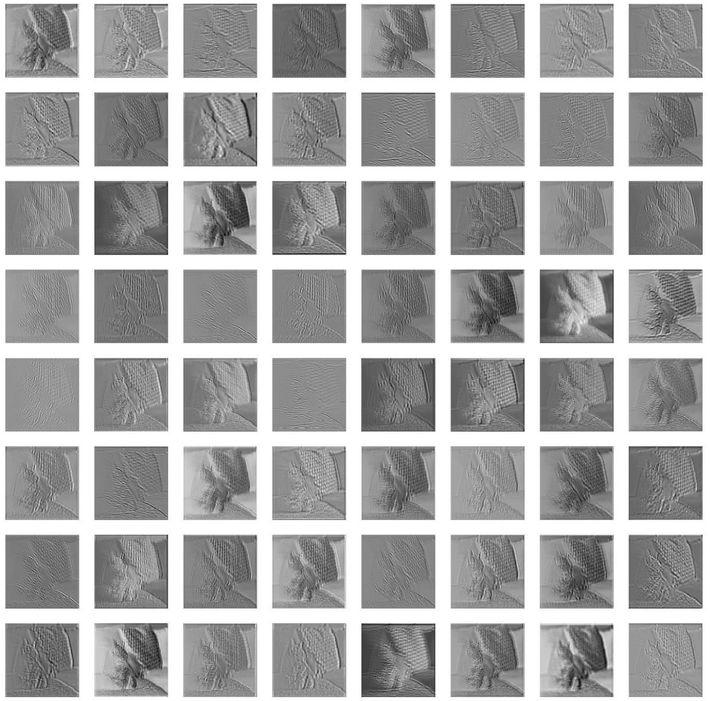
Feature Maps

Feature maps from the last convolutional layer (layer 0) of ResNet-50



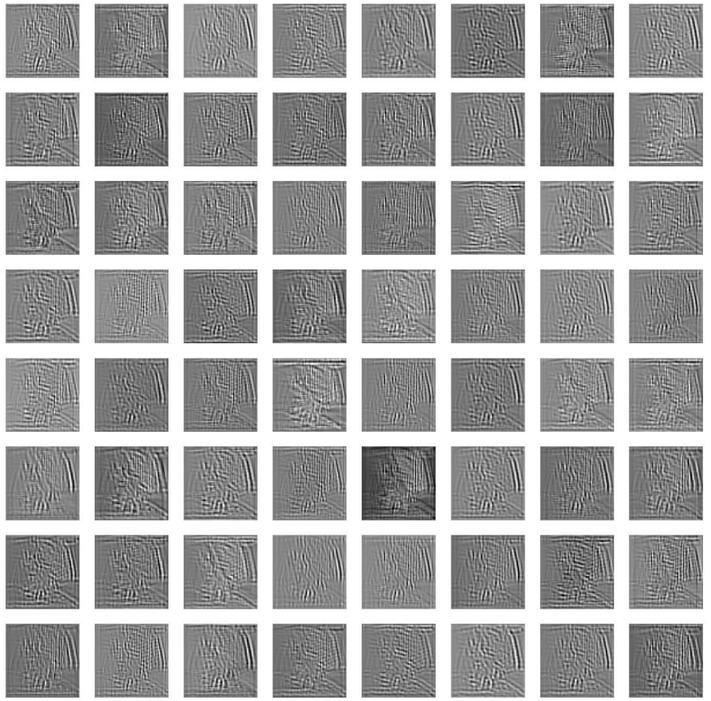
Feature Maps (Contd.)

Feature maps from the last convolutional layer (layer 20) of ResNet-50



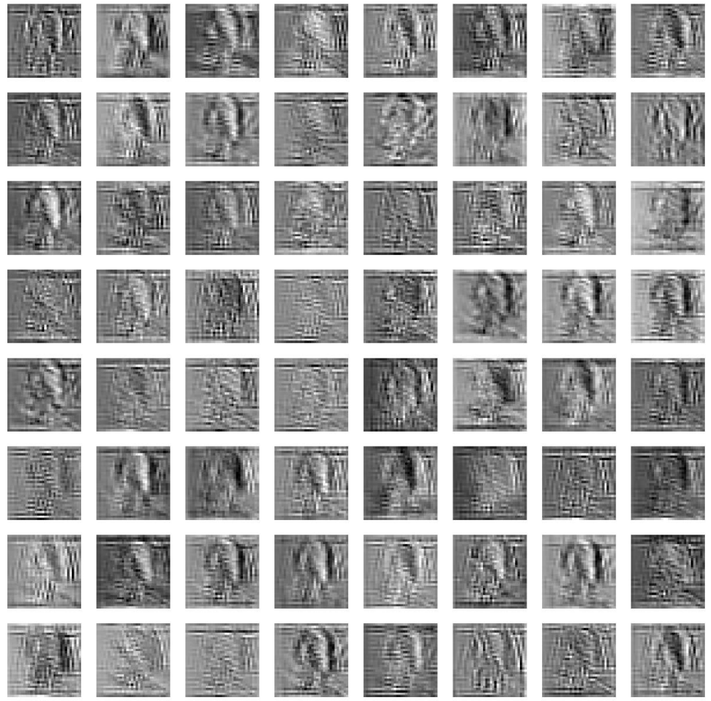
Feature Maps (Contd.)

Feature maps from the last convolutional layer (layer 40) of ResNet-50



Feature Maps (Contd.)

Feature maps from the last convolutional layer (layer 44) of ResNet-50



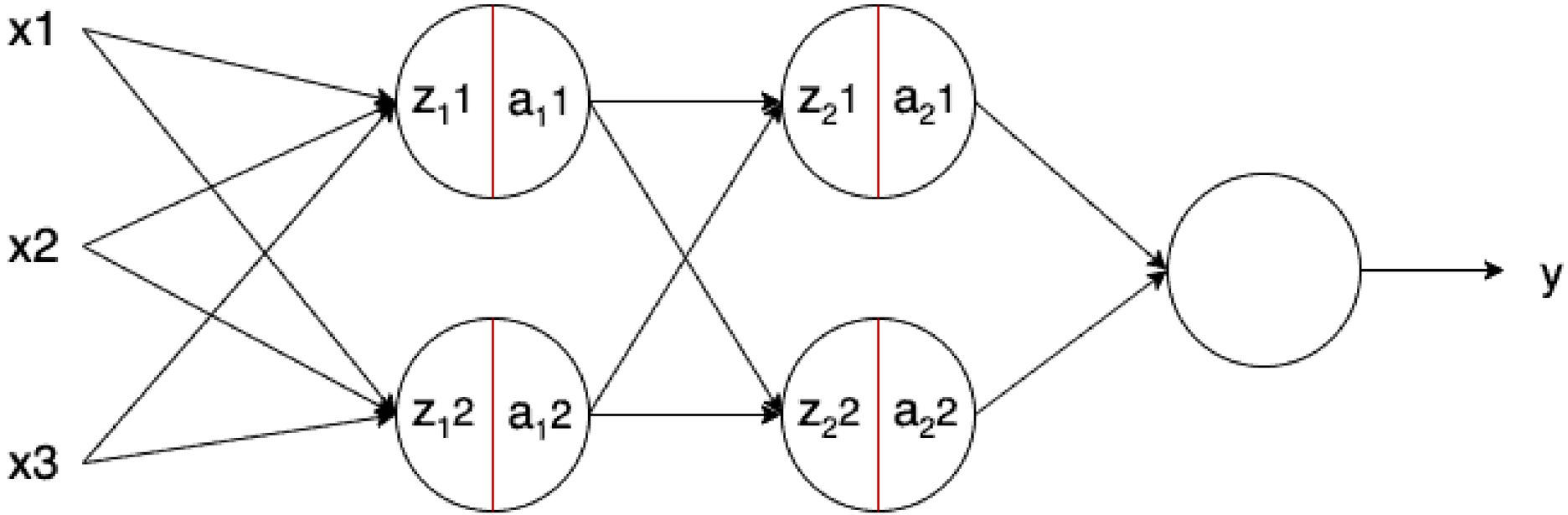
Feature Maps (Contd.)

Feature maps from the last convolutional layer (layer 48) of ResNet-50

Normalization and Image Augmentation

Batch Normalization

Batch Norm is a normalization technique done between the layers of a Neural Network instead of in the raw data.



Augmentation in CNN

Augmentation	Purpose
Horizontal Flip	Learn symmetry, prevent left/right bias
Rotation	Learn object at various orientations
Random Crop	Learn from partial views
Color Jitter	Handle brightness/contrast variance
Affine Transform	Robust to distortion/rotation/scale

Horizontal Flip

Original Image

Horizontal Flip

Rotation

Rotation: 15°

Rotation: 45°

Rotation: 90°

Random Crop

Original Image

Random Crop (224x224)

Color Jitter

Original Image

Color Jitter Applied

MNIST Classification with CNN and Filter Analysis (Demonstration)

Note: Refer to the Module 3: Demo 1 on LMS for detailed steps.

Summary

In this lesson, you have learned to:

- Grasp the fundamental concepts and applications of CNNs.
- Understand how to represent images for input to CNNs.
- Explore how convolution and pooling operations work to extract features from images.
- Recognize the structure and components that make up CNN architectures.
- Visualize feature maps and apply techniques like normalization and data augmentation to improve model performance.

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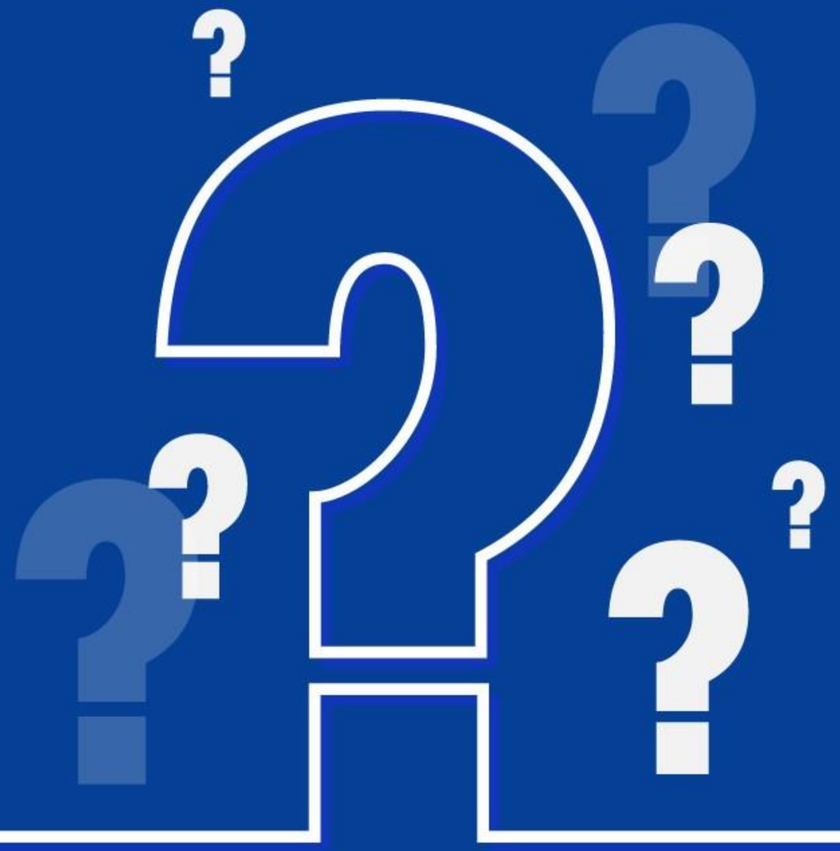
Questions



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Feedback

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Thank You

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