Short Course on Deep Learning and Convolutional Neural Network

Day 1: Machine Learning Basics

Introduction to Image Processing

Type of Machine Learning Systems

Type of Machine Learning Systems

Supervised Learning
Unsupervised Learning
Semi-supervised Learning
Reinforcement Learning

Depending on whether the system is trained with human supervision

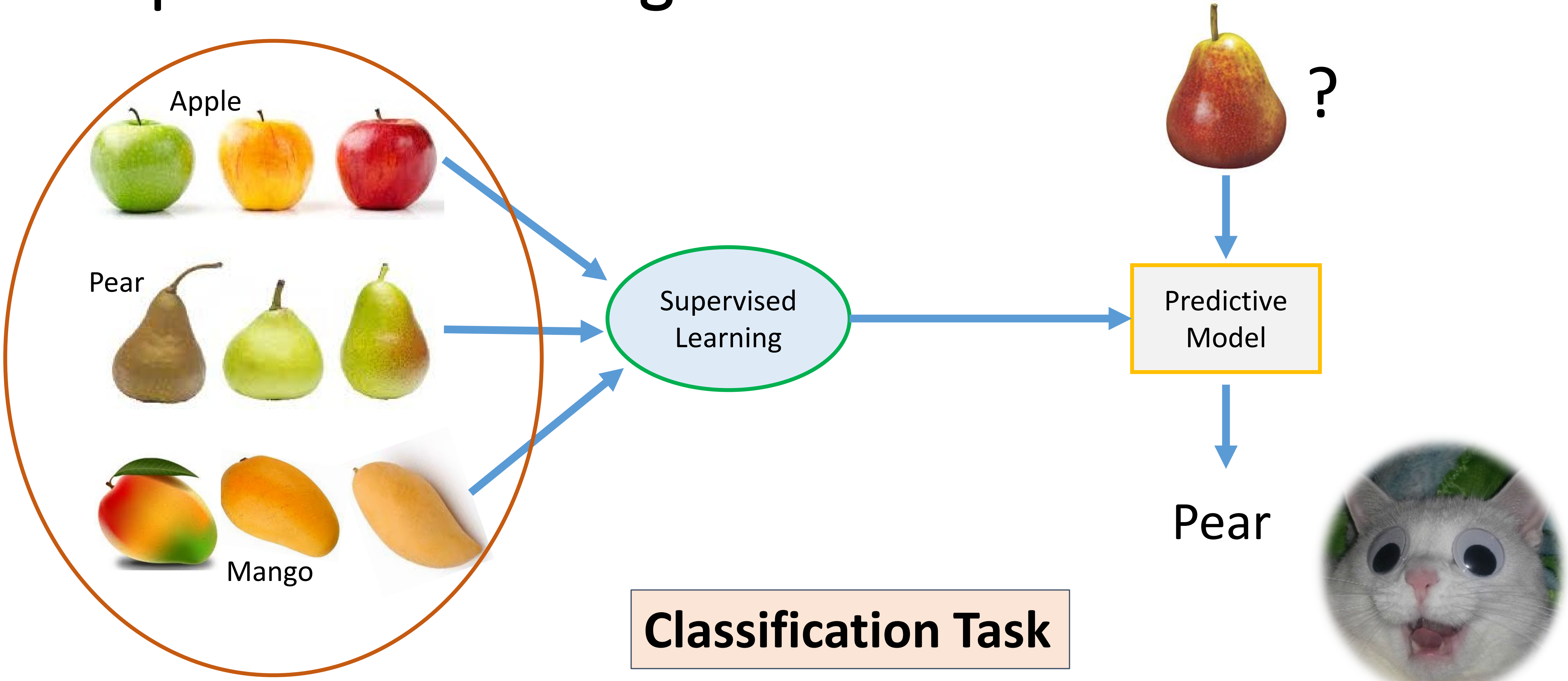
Batch and Online Learning

Whether System can learn on the fly

Instance-based and Model-based Learning

Comparing data points or detect patterns in training data to build a predictive model

Supervised Learning



Labelled data for training
(Object + Desired Output Label)

Supervised Learning

House Price prediction

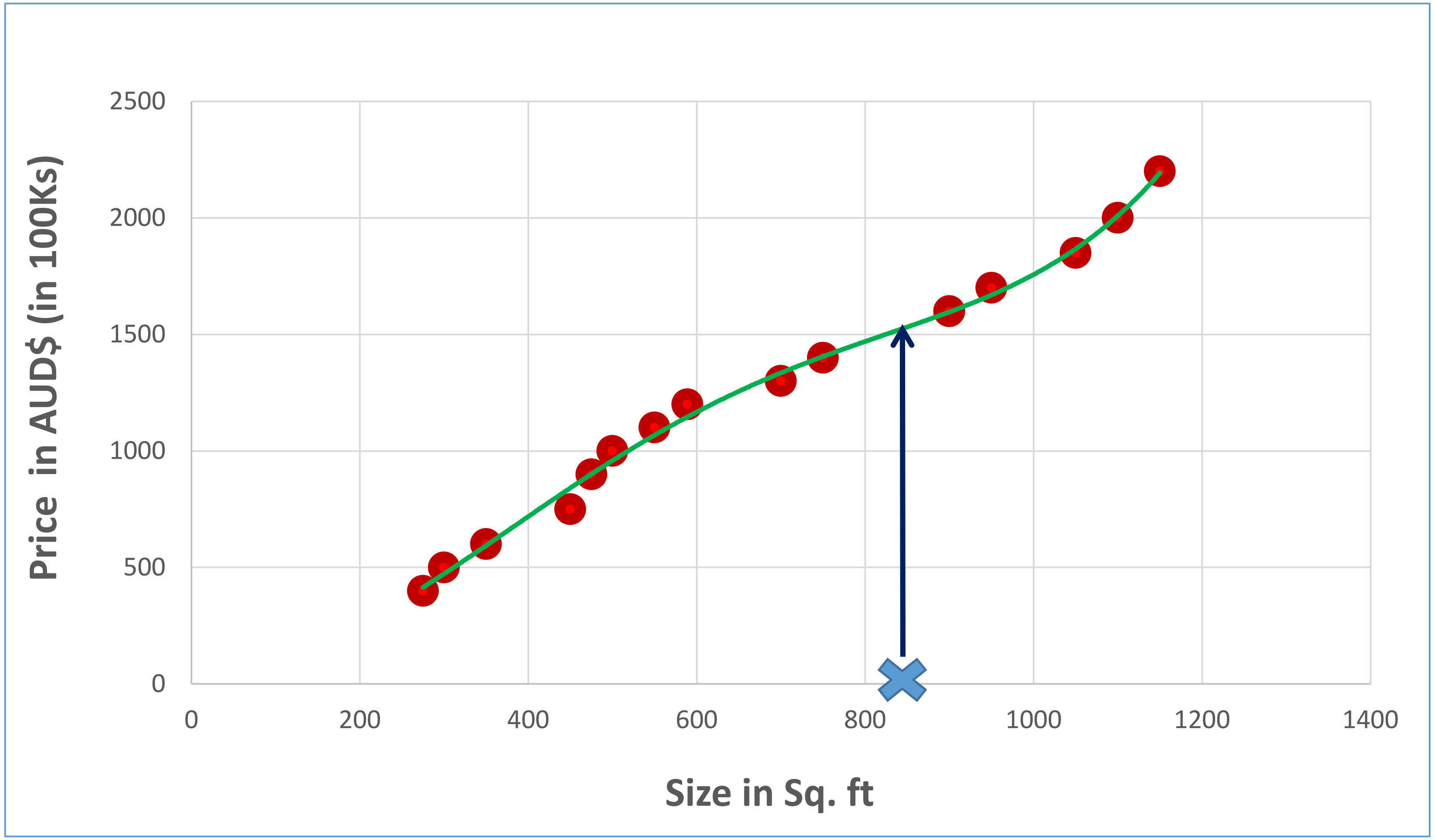
Feature:

- Size of the house

To Predict:

- Price of the house

Regression Task

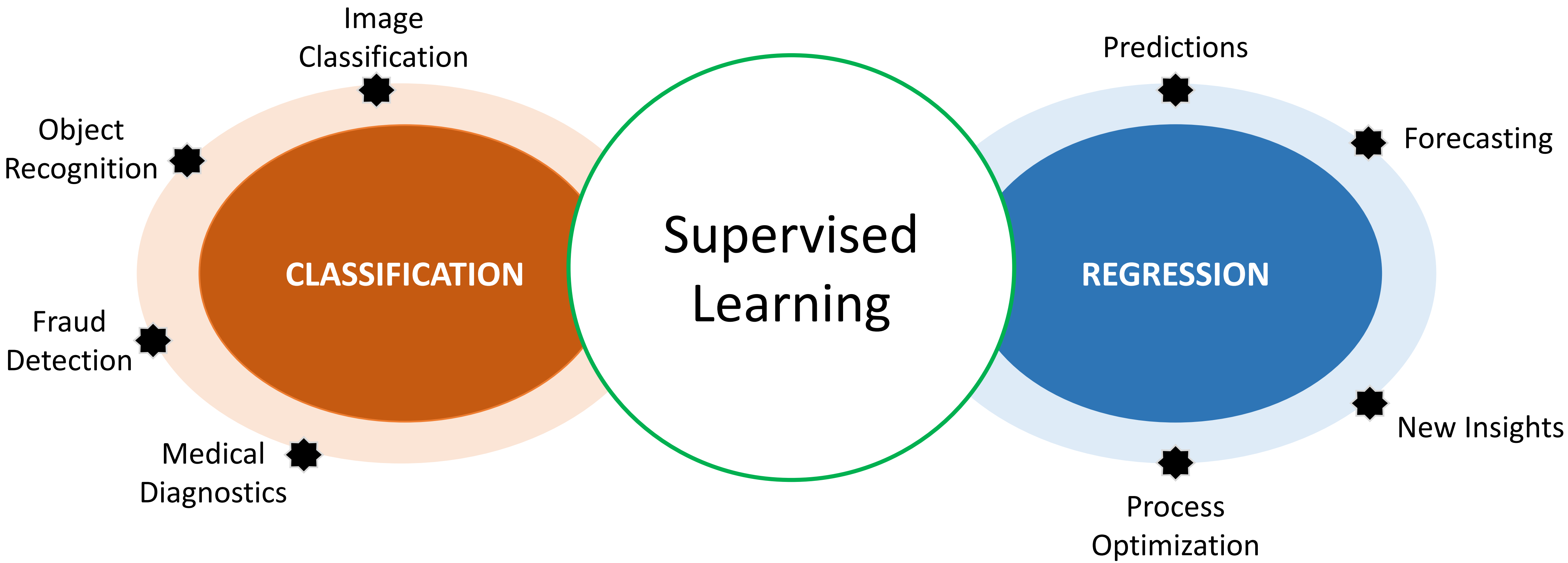


Supervised Learning

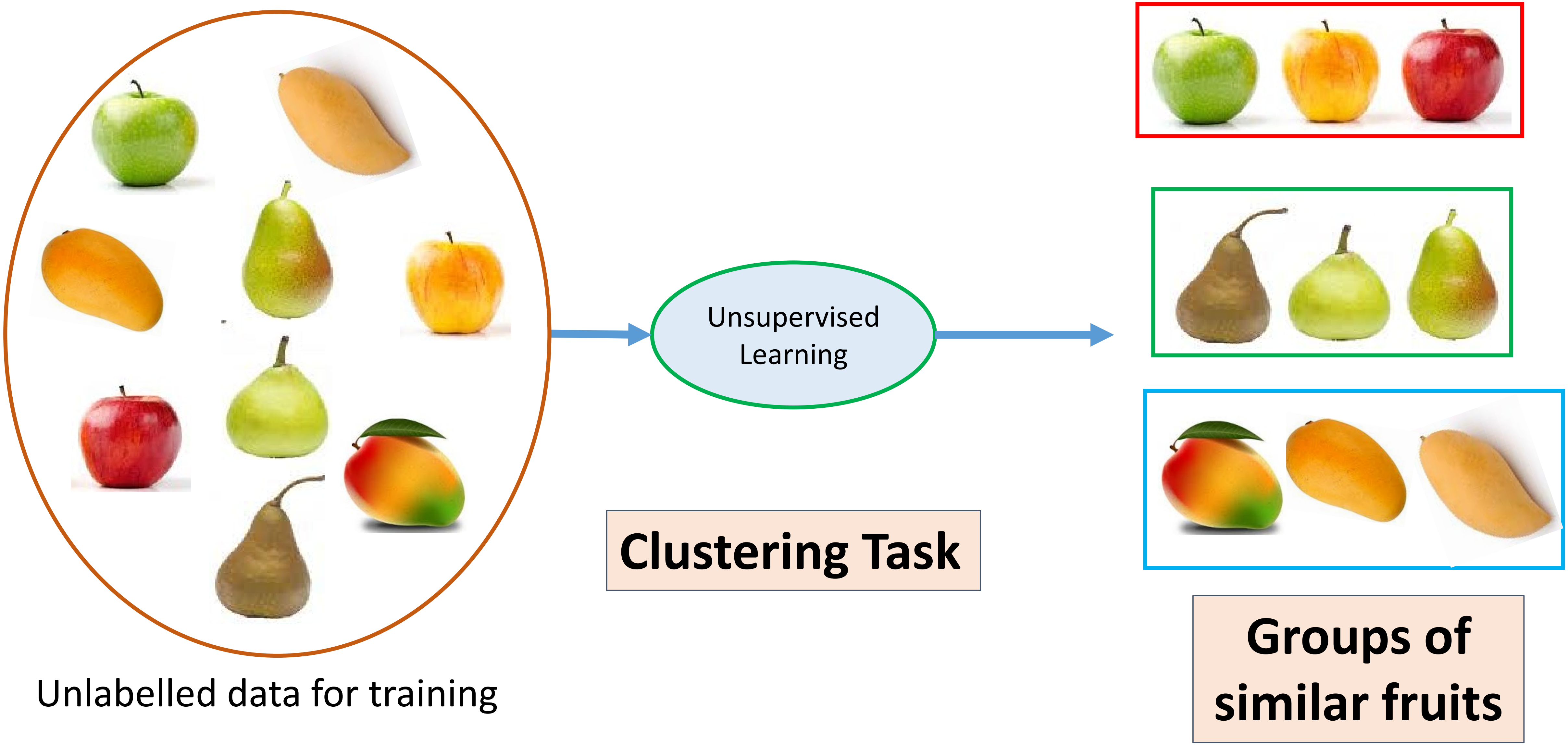
Important Algorithms:

- K-Nearest Neighbours
- Logistic regression
- Support Vector Machines (SVMs)
- Neural Networks (*some of them can be unsupervised)

Supervised Learning Examples



Unsupervised Learning



Unsupervised Learning

Important Algorithms:

- k-means
- Expectation Maximization

Support Vector Machines (SVM)

- A Support Vector Machine is a very powerful and versatile Machine Learning model, capable of performing linear or non-linear classification, regression, and also outlier detection.
- Defined by a separating hyperplane
- Suitable for small or medium sized datasets

Reference and Pre-Reading:

Theory: https://medium.com/machine-learning-101/chapter-2-svm-support-vector-machine-theory-f0812effc72
Implementation: https://medium.com/machine-learning-101/chapter-2-svm-support-vector-machine-coding-edd8f1cf8f2d

Support Vector Machines (SVM)

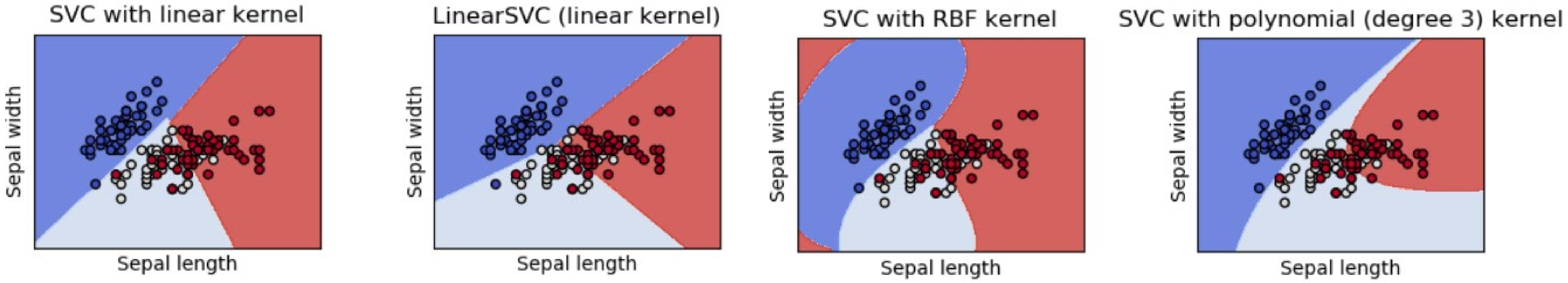
Example: Using sklearn for SVM classification (Partial code snippet)

```
import numpy as np
import matplotlib.pyplot as plt
from sklearn import svm, datasets

# import some data to play with
iris = datasets.load_iris()
# Take the first two features. We could avoid this by using a two-dim dataset
X = iris.data[:, :2]
y = iris.target

# we create an instance of SVM and fit out data. We do not scale our
# data since we want to plot the support vectors
C = 1.0  # SVM regularization parameter
models = (svm.SVC(kernel='linear', C=C),
          svm.LinearSVC(C=C),
          svm.SVC(kernel='rbf', gamma=0.7, C=C),
          svm.SVC(kernel='poly', degree=3, C=C))
models = (clf.fit(X, y) for clf in models)
```

Reference: https://scikit-learn.org/stable/auto_examples/svm/plot_iris.html#sphx-glr-auto-examples-svm-plot-iris-py
https://en.wikipedia.org/wiki/Iris_flower_data_set

Support Vector Machines (SVM)

Example: Using sklearn for SVM classification



Reference: https://scikit-learn.org/stable/auto_examples/svm/plot_iris.html#sphx-glr-auto-examples-svm-plot-iris-py
https://en.wikipedia.org/wiki/Iris_flower_data_set

K-Nearest Neighbour (KNN)

- A simple supervised learning algorithm.
- Can be used for both classification and regression
- Non-parametric: doesn’t make any assumption on the data distribution
- Training data is retained to make future predictions

Reference and Pre-Reading: https://towardsdatascience.com/knn-using-scikit-learn-c6bed765be75
https://scikit-learn.org/stable/modules/neighbors.html

K-Nearest Neighbour (KNN)

How does it work?

- Computes distance between the new sample and all training samples
- Distance measure: Euclidean, Manhattan etc.
- Picks ‘k’ entries in the training set which are closest to the new sample
- Majority voting decides the class of the new sample

Reference and Pre-Reading: https://towardsdatascience.com/knn-using-scikit-learn-c6bed765be75
https://scikit-learn.org/stable/modules/neighbors.html

K-Nearest Neighbour (KNN)

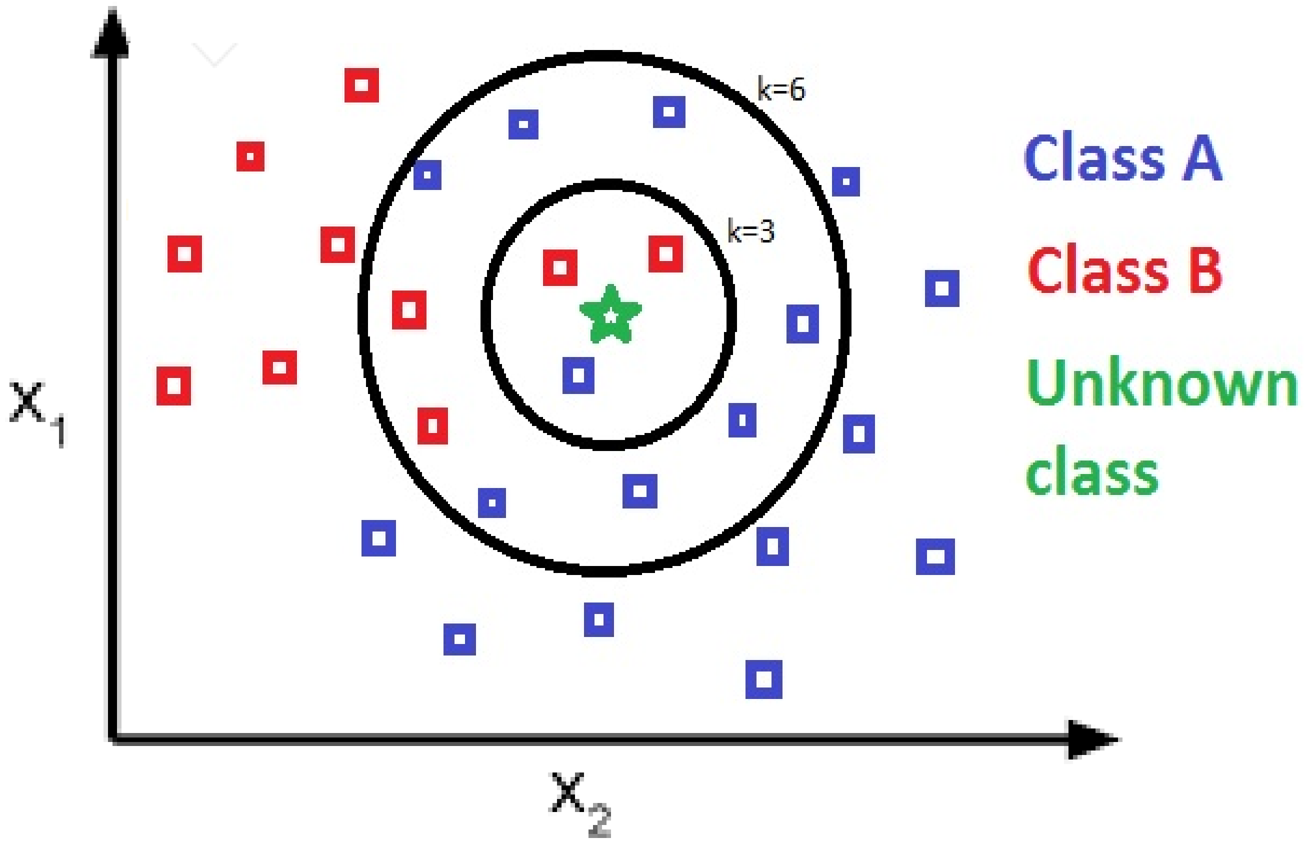


Image Source: https://towardsdatascience.com/knn-using-scikit-learn-c6bed765be75
https://scikit-learn.org/stable/modules/neighbors.html

Evaluation Metrics

- **Precision & Recall**

What are the “correct” cells?

- *TN:* (Number of True Negatives), i.e., patients who did *not* have cancer whom we correctly diagnosed as *not* having cancer.

- *TP:* (Number of True Positives), i.e., patients who did have cancer whom we correctly diagnosed as having cancer

Precision: TP/Cancer Diagnoses

Diagnoses

True state	**No Cancer**	**Cancer**
No Cancer	TN	FP
Cancer	FN	TP

Recall: TP/Cancer True States

Evaluation Metrics

- **Precision & Recall**

what are the “error” cells are:

- *FN:* (Number of False Negatives),
  i.e., patients who did have cancer whom we incorrectly diagnosed as *not* having cancer

- *FP:* (Number of False Positives),
  i.e., patients who did *not* have cancer whom we incorrectly diagnosed as having cancer

Precision: TP/Cancer Diagnoses

Diagnoses

True state		No Cancer	Cancer
	No Cancer	TN	FP
	Cancer	FN	TP

Recall: TP/Cancer True States

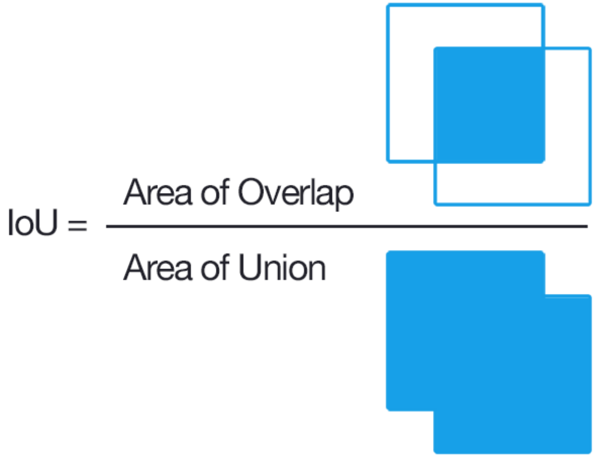
$\text{Precision} = (TP)/(TP+FP)$

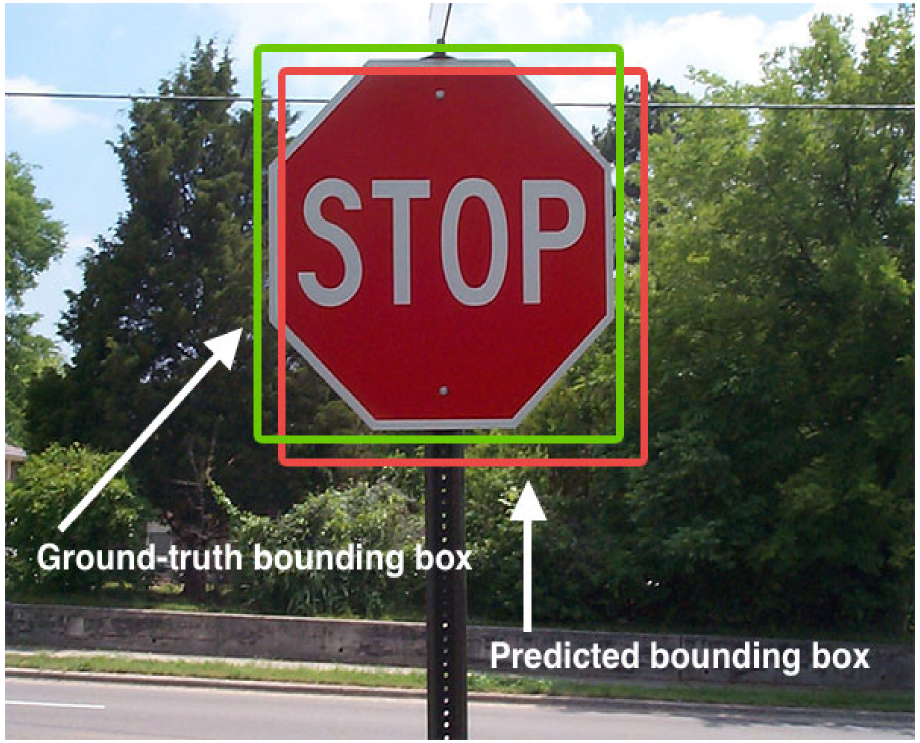
$\text{Recall} = (TP)/(TP+FN)$

Evaluation Metrics

- **Intersection over Union (IoU):**

Intersection over Union is a metric used for the evaluation of an object detector, i.e. how good is the predicted bounding box for an object detected closely matches





Reference: https://www.pyimagesearch.com/2016/11/07/intersection-over-union-iou-for-object-detection/

Image Processing Basics

Image Processing Basics

What is a digital image?

- Digital images are made of picture elements called ***Pixels.***
- It is an array, or a matrix of ***Pixels*** arranges in *columns* and *rows*.
- Each ***Pixel*** has its own *intensity* value, or *brightness*

- Intensity values in digital images are defined by ***bits***
- For a standard 8 bits image, a pixel can have $2^8 = 256$ (0 – 255) values.
- Black & White images have a single 8-bits intensity range.

Image Processing Basics

Image dimension = 5 X 5

***f*(2, 3) = 170 (Pixel/intensity value)**

Hence, an image may be defined as a 2D function ***f*(x, y)** , where, *x* and *y* are spatial co-ordinates, and the amplitude of ***f*** at **(*x* , *y*)** is the intensity or Gray level of the image at that point/pixel.

170	170	55	170	170
170	55	170	55	170
170	55	170	55	170
55	140	140	140	55
55	170	170	170	55

5 X 5 Gray scale image (8 bit)

Image Processing Basics

Image dimension = 5 X 5 X 3

No. of Channels = 3

Since, RGB image contains 3 X 8-bits of intensities, they are referred to as 24-bit colour images.

So, 24-bit colour depth

= 8 X 8 X 8 bits

= 256 X 256 X 256 colours

= ~16 million colours

5 X 5 X 3 colour image (24 bit)

Image Thresholding

- Easiest method for image segmentation!
- Converts gray-scale image into a binary image

If *f(x,y) > Threshold*, then *f(x,y) = 0* else *f(x,y) = 255*

Binary Image (8-bit) has only two possible values of pixel intensity (0 and 1, or B & W)

170	170	55	170	170
170	55	170	55	170
170	55	170	55	170
55	140	140	140	55
55	170	170	170	55

Threshold = 100

255	255	0	255	255
255	0	255	0	255
255	0	255	0	255
0	255	255	255	0
0	255	255	255	0

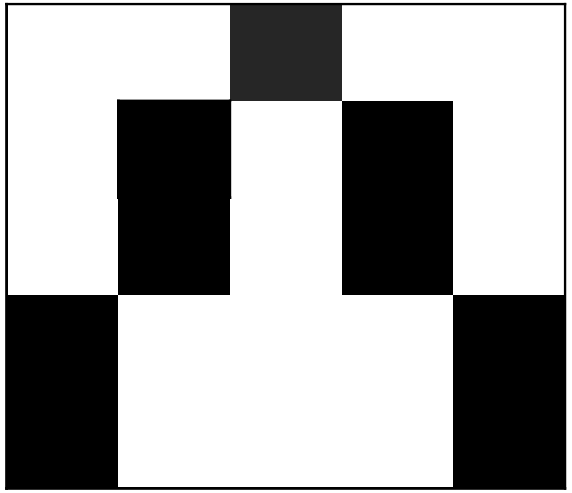


Image Thresholding

Original Image

Thresholding

Binary Image

Image Source: https://en.wikipedia.org/wiki/Thresholding_(image_processing)

Image Thresholding methods

- **Histogram shape:**

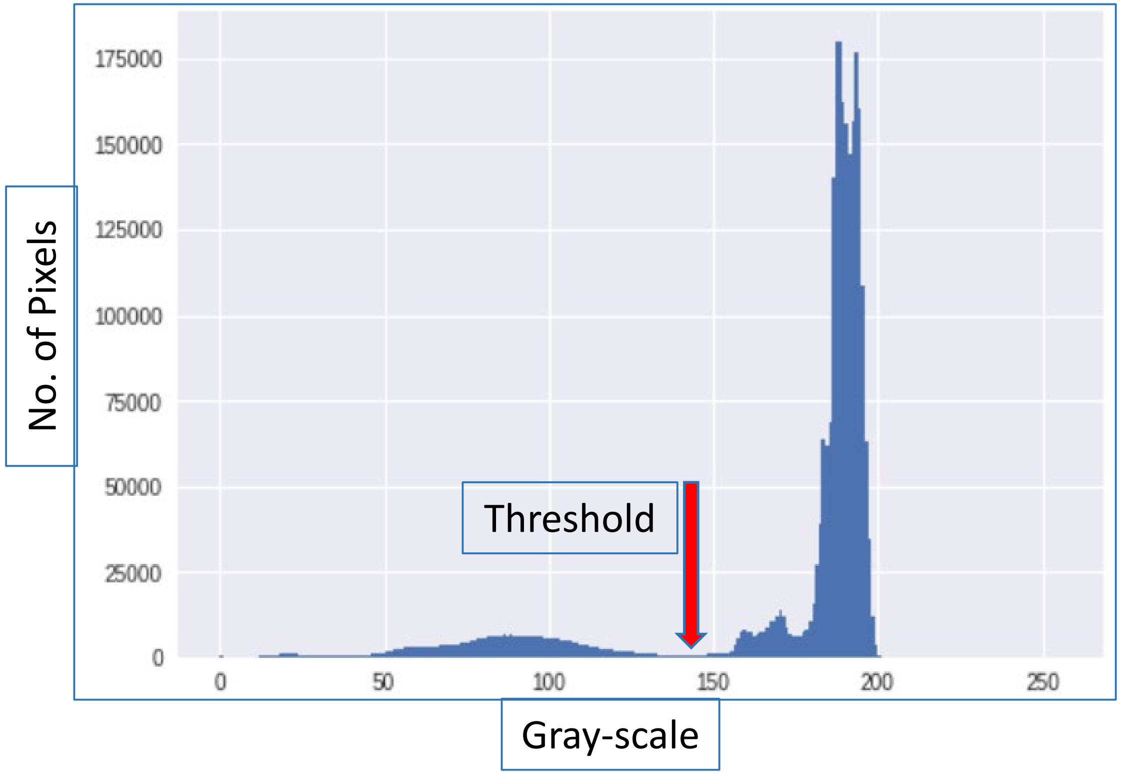
Peaks, valleys and curvature of the histogram are analysed.

- **Clustering based:**

The [1]Otsu method, very good for bimodal distribution

- **Adaptive thresholding:**

Instead of a single threshold, have thresholds for different regions in the image

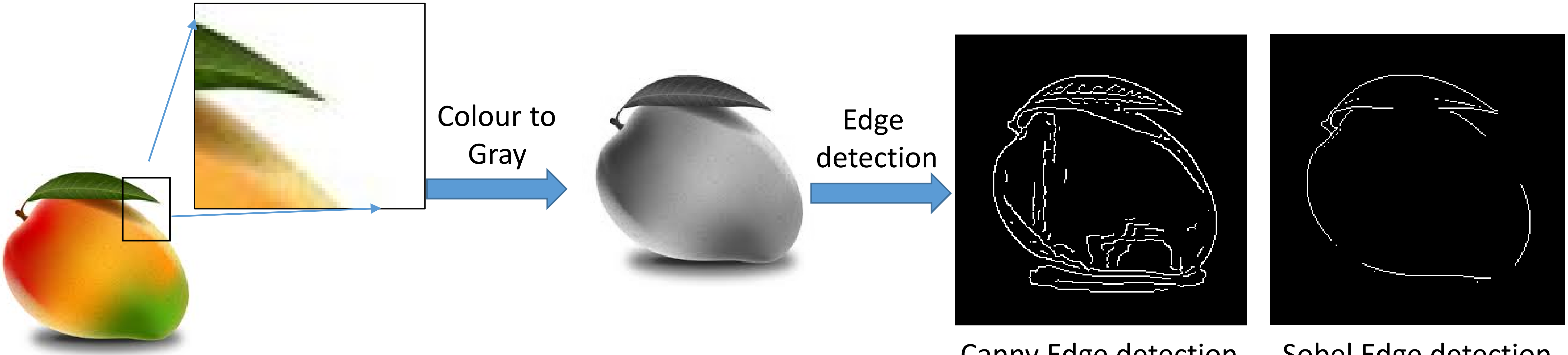


[1]Reference: https://en.wikipedia.org/wiki/Otsu%27s_method

Edge Detection

What is an edge?

- The points/pixels in an image where brightness/intensities changes sharply
- A simple and fundamental tools in image processing and computer vision, useful in feature detection/extraction



Canny Edge detection   Sobel Edge detection

How to find Edges in images? (Convolution)

100	**100**	**100**	**0**	**0**	**0**
100	100	100	**0**	**0**	**0**
100	100	100	**0**	**0**	**0**
100	100	100	**0**	**0**	**0**
100	100	100	**0**	**0**	**0**
100	100	100	**0**	**0**	**0**

6 X 6 dimension image

*

Convolution operator

1	**0**	**-1**
1	0	-1
1	0	-1

3 X 3 filter/Kernel

0	**300**	**300**	**0**
0	300	300	**0**
0	300	300	**0**
0	300	300	**0**

4 X 4 dimension matrix

How to find Edges in images? (Convolution)

(100 X 1 + 100 X 1 + 100 X 1) +
(100 X 0 + 100 X 0 + 100 X 0) +
(100 X -1 + 100 X -1 + 100 X -1)

1 100	0 100	-1 100	**0**	**0**	**0**
1 100	0 100	-1 100	**0**	**0**	**0**
1 100	0 100	-1 100	**0**	**0**	**0**
100	100	100	**0**	**0**	**0**
100	100	100	**0**	**0**	**0**
100	100	100	**0**	**0**	**0**

6 X 6 dimension image

$*$

Convolution operator

1	**0**	**-1**
1	0	-1
1	0	-1

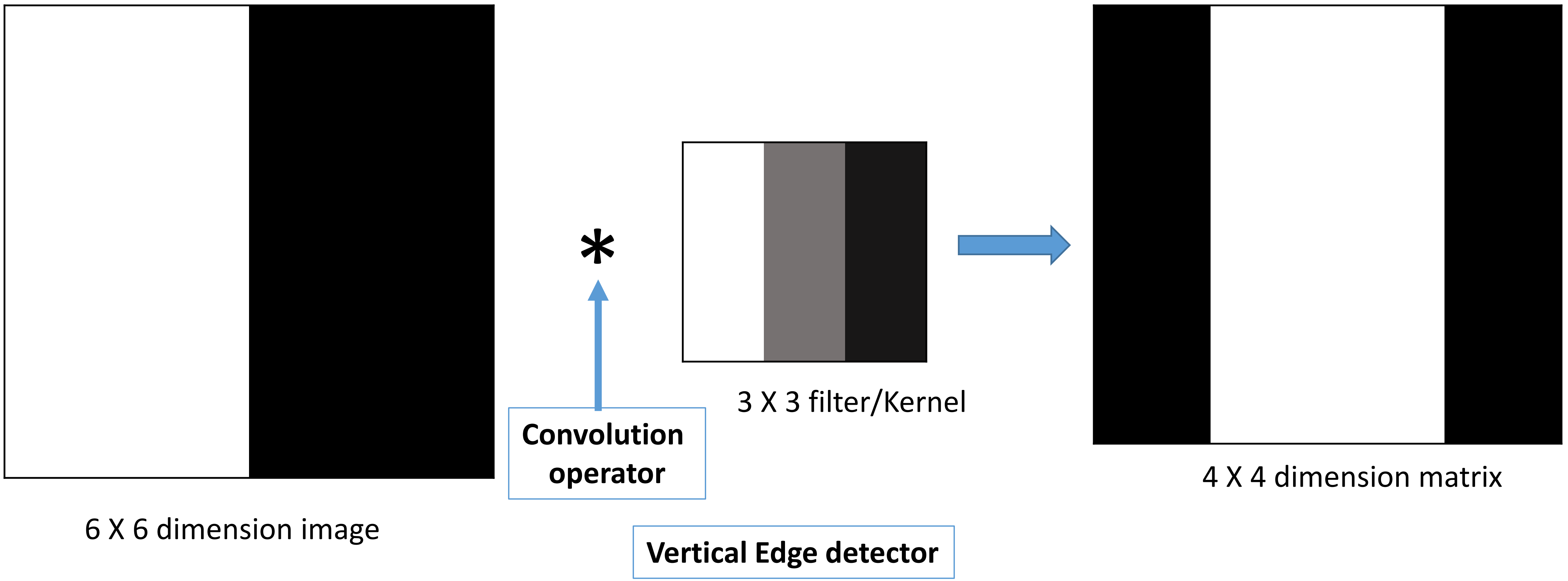
3 X 3 filter/Kernel

Vertical Edge detector

0	**300**	**300**	**0**
0	300	300	**0**
0	300	300	**0**
0	300	300	**0**

4 X 4 dimension matrix

How to find Edges in images? (Convolution)



How to find Edges in images? (Convolution)

100	**100**	**100**	**100**	**100**	**100**
100	100	100	100	100	100
100	100	100	100	100	100
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0

6 X 6 dimension image

*

Convolution operator

1	**1**	**1**
0	0	0
-1	-1	-1

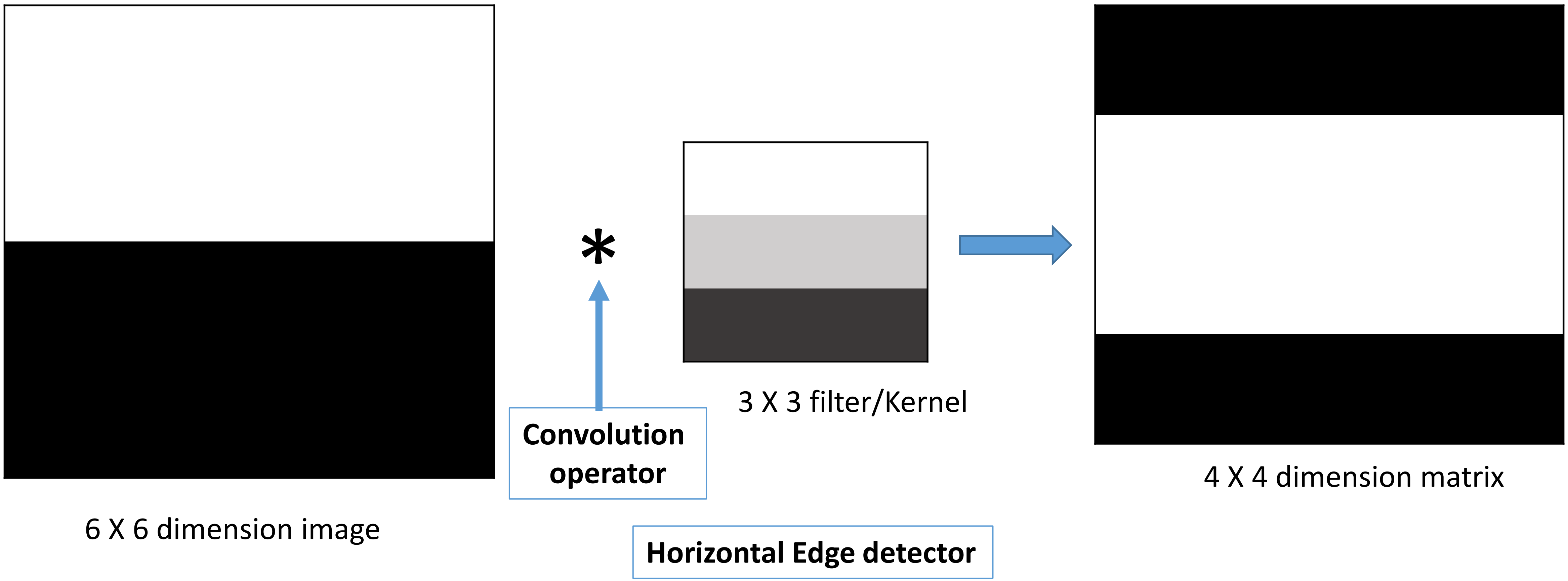
3 X 3 filter/Kernel

Horizontal Edge detector

0	**0**	**0**	**0**
300	300	300	300
300	300	300	300
0	0	0	**0**

4 X 4 dimension matrix

How to find Edges in images? (Convolution)



Sobel edge detection

1	**0**	**-1**
1	0	-1
1	0	-1

3 X 3 filter/Kernel
For Vertical edges

1	**1**	**1**
0	0	0
-1	-1	-1

3 X 3 filter/Kernel
For Horizontal edges

Prewitt Filters

1	**2**	**1**
0	0	0
-1	-2	-1

3 X 3 filter/Kernel
For Horizontal edges

1	**0**	**-1**
2	0	-2
1	0	-1

3 X 3 filter/Kernel
For Vertical edges

Sobel Filters

Sobel edge detection

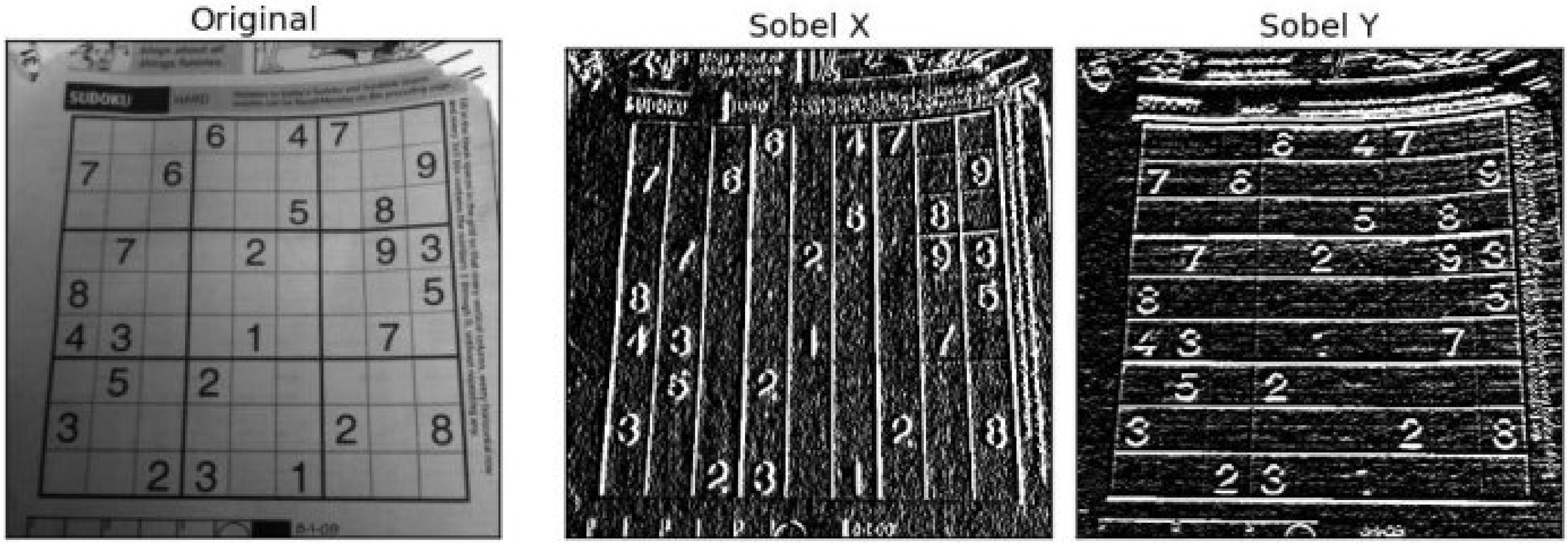


Image Source: https://docs.opencv.org/3.0-beta/doc/py_tutorials/py_imgproc/py_gradients/py_gradients.html

Convolutions in CNN

- Convolutions are very important operation in a Convolutional Neural Networks (CNN)
- Filters weights are not fixed, but learned during the training operations of a CNN for a specific task!
- Multiple filters are used in CNNs