Introduction to **Image Processing** & **Computer Vision**

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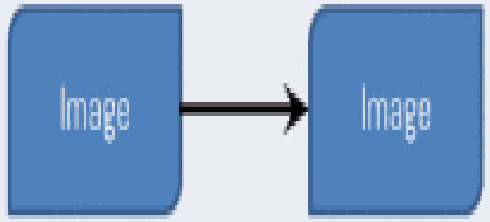
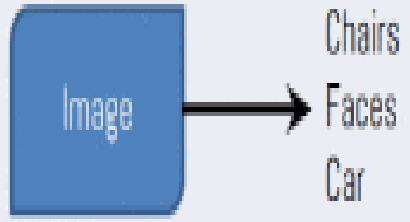
Agenda

- Introduction to Image processing
- Image Noise
- Removal of Noise from Images
- Color Enhancement
- Segmentation
- Edge Detection

Image Processing	Computer Vision
Research area within Electrical Engineering / Signal Processing	Research area within Computer Science / Artificial Intelligence
Focus on syntax and low-level architectures	Focus on semantic, symbolic and geometric descriptions
Converts one image into another [IMG IN] → [IMG OUT]	Extracts features from image [IMG IN] → Measurements, Description
	

What is Digital Image Processing?
What is Computer Vision?

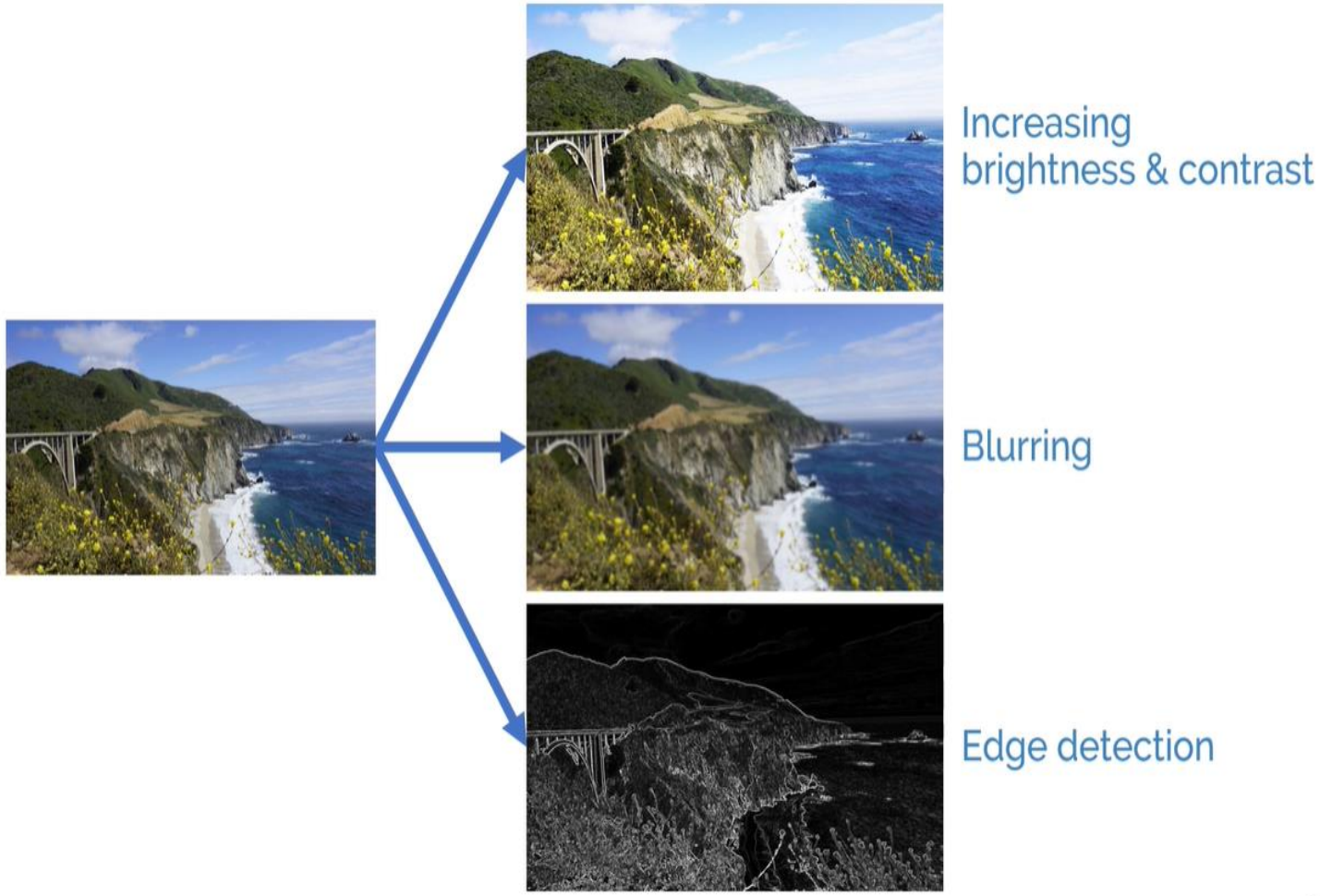
- Digital Image Processing refers to processing digital images by means of a digital computer.
- Computer Vision refers to deep image analysis, recognition of objects located in digital images and to simulation of the cognitive functions normally associated with vision.

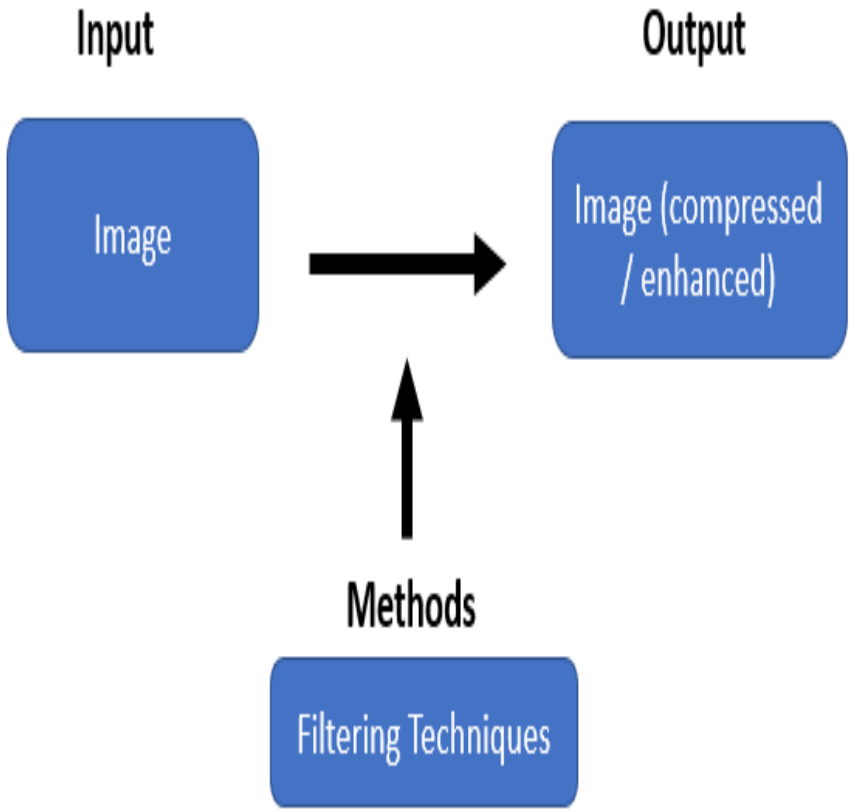
Introduction to Image processing

- Image processing is a method to perform some operations on an image, in order to get an enhanced image or to extract some useful information from it.
- It is a type of signal processing in which input is an image and output may be image or characteristics/features associated with that image.
- Image processing basically includes the following three steps:

    1. Importing the image via image acquisition tools;
    2. Analyzing and manipulating the image;
    3. Output in which result can be altered image or report that is based on image analysis.

What is image acquisition



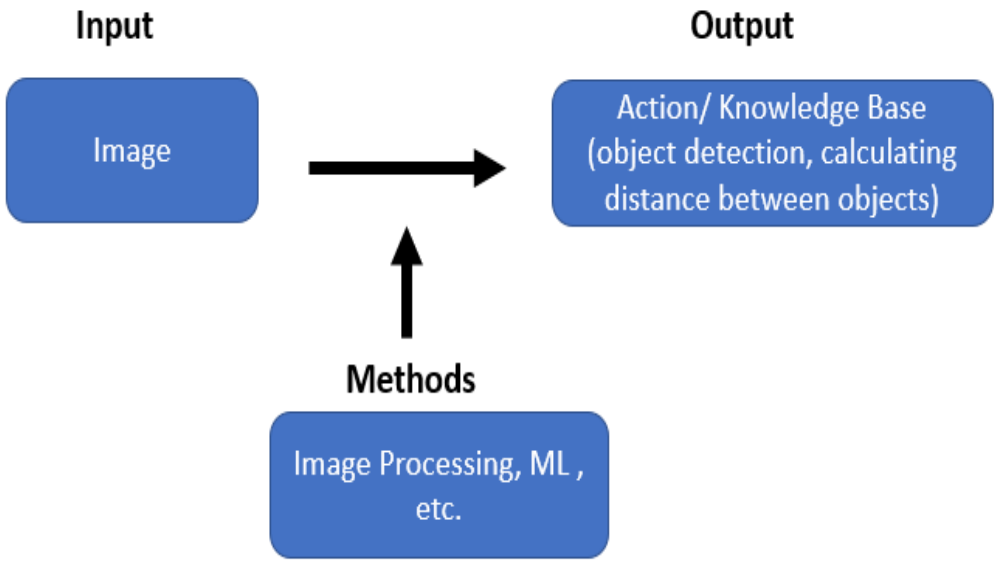


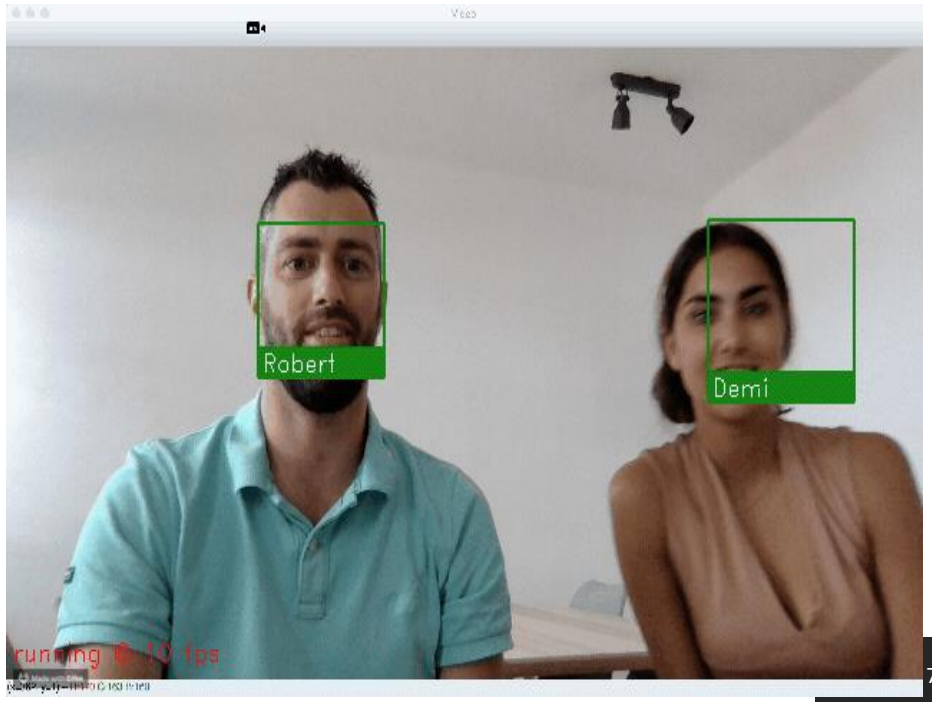
Areas of Application of Digital Image Processing

- Aerospace Imaging
- Medical Imaging
- Digital Photography
- Surveillance Systems
- Security and Intelligence
- Nondestructive Check
- Remote Sensing

Computer Vision

- To emulate human vision, including learning and being able to make inferences and take actions based on visual inputs.
- It is concerned with the automatic extraction, analysis and understanding of useful information from a single image or a sequence of images.





Computer Vision

- Visual scene → extract → a task relevent information
- Examples
  - Optical character recognition
  - Analysis of medical, satellite and microscopic images
  - Surveillance
  - Identity verification
  - Quality control in manufacturing

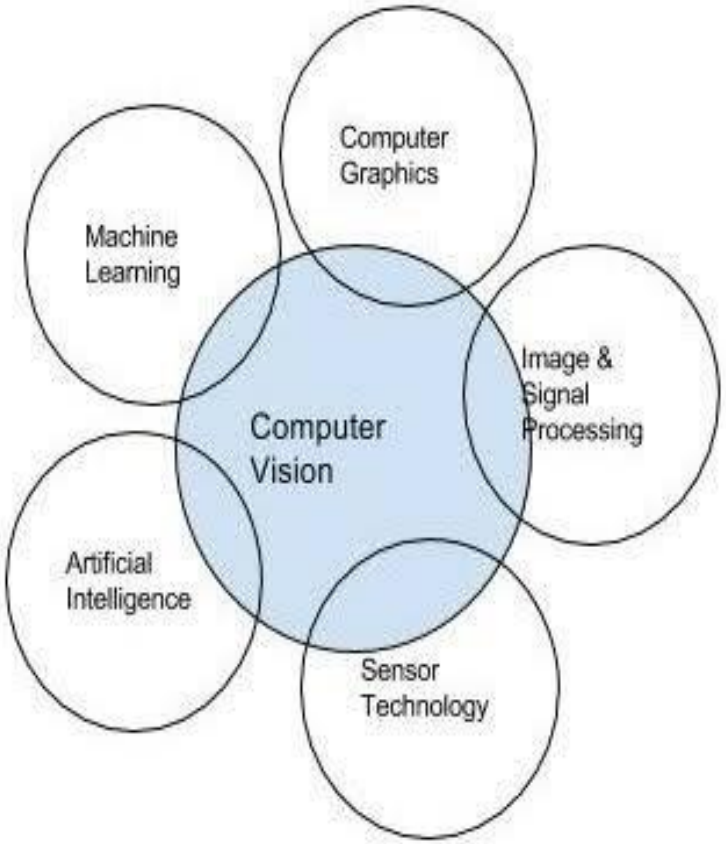
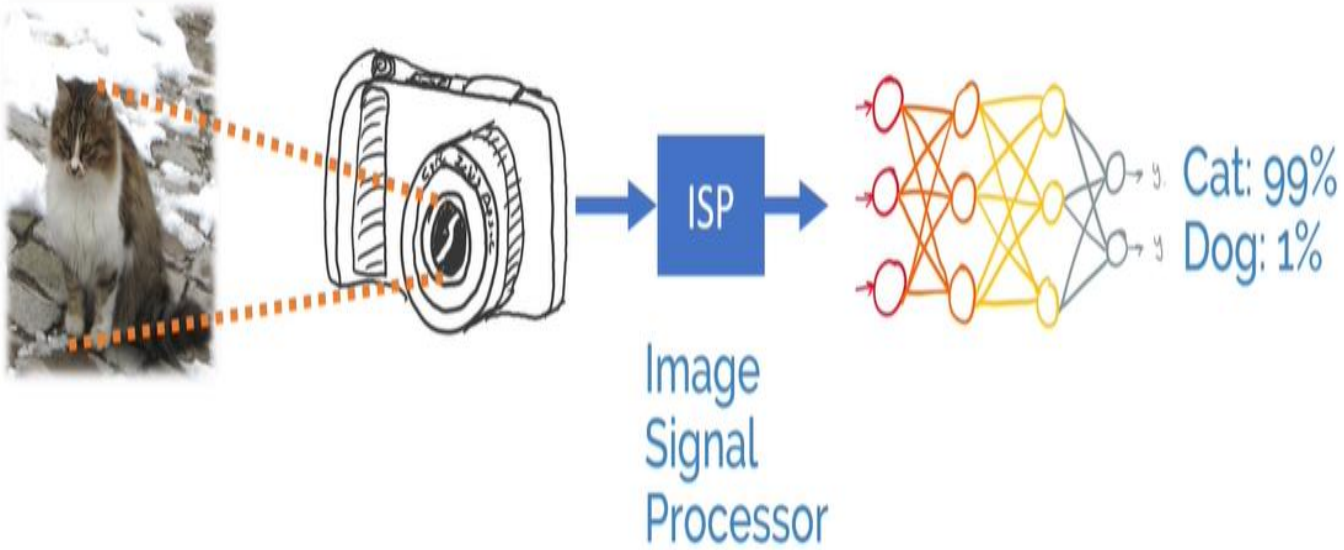


Image Processing + Computer Vision



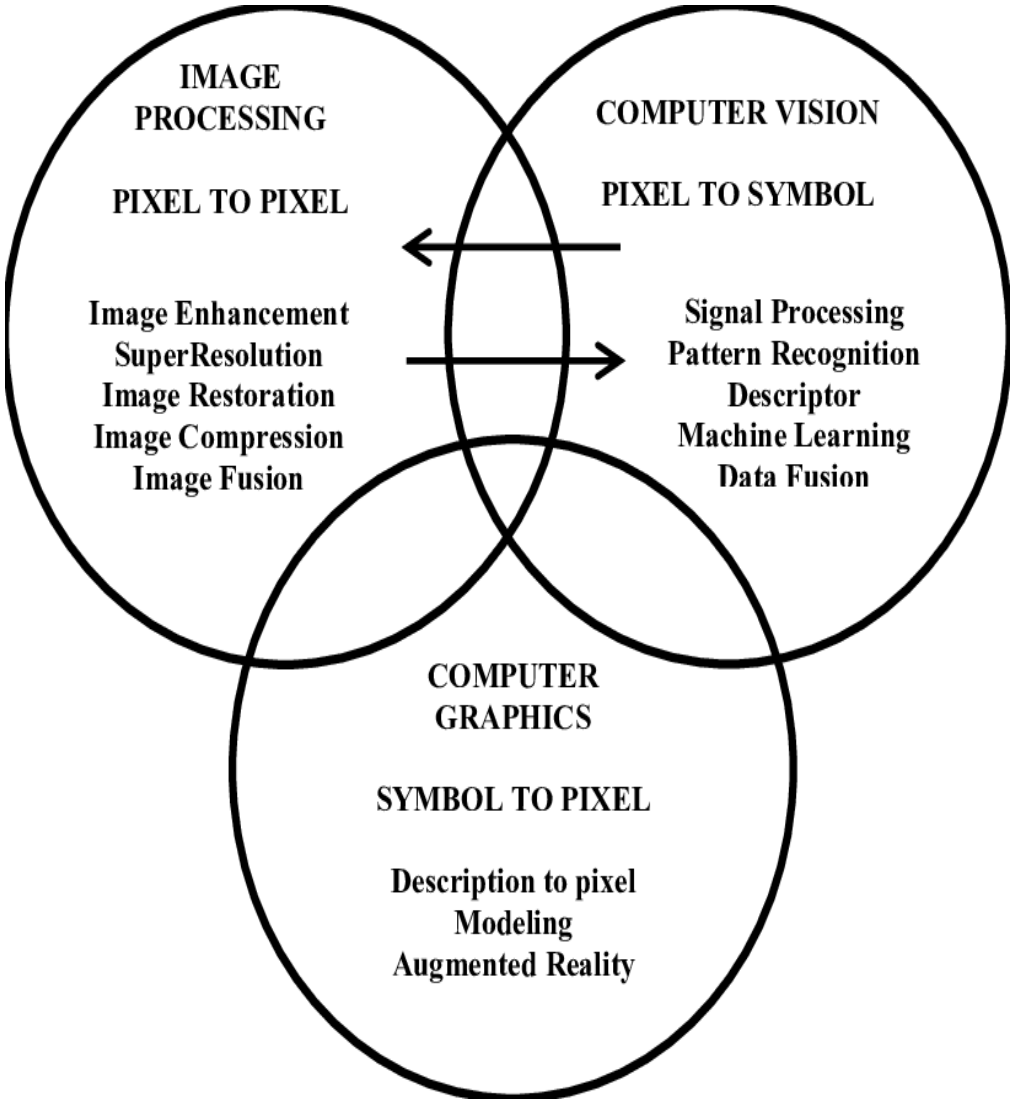
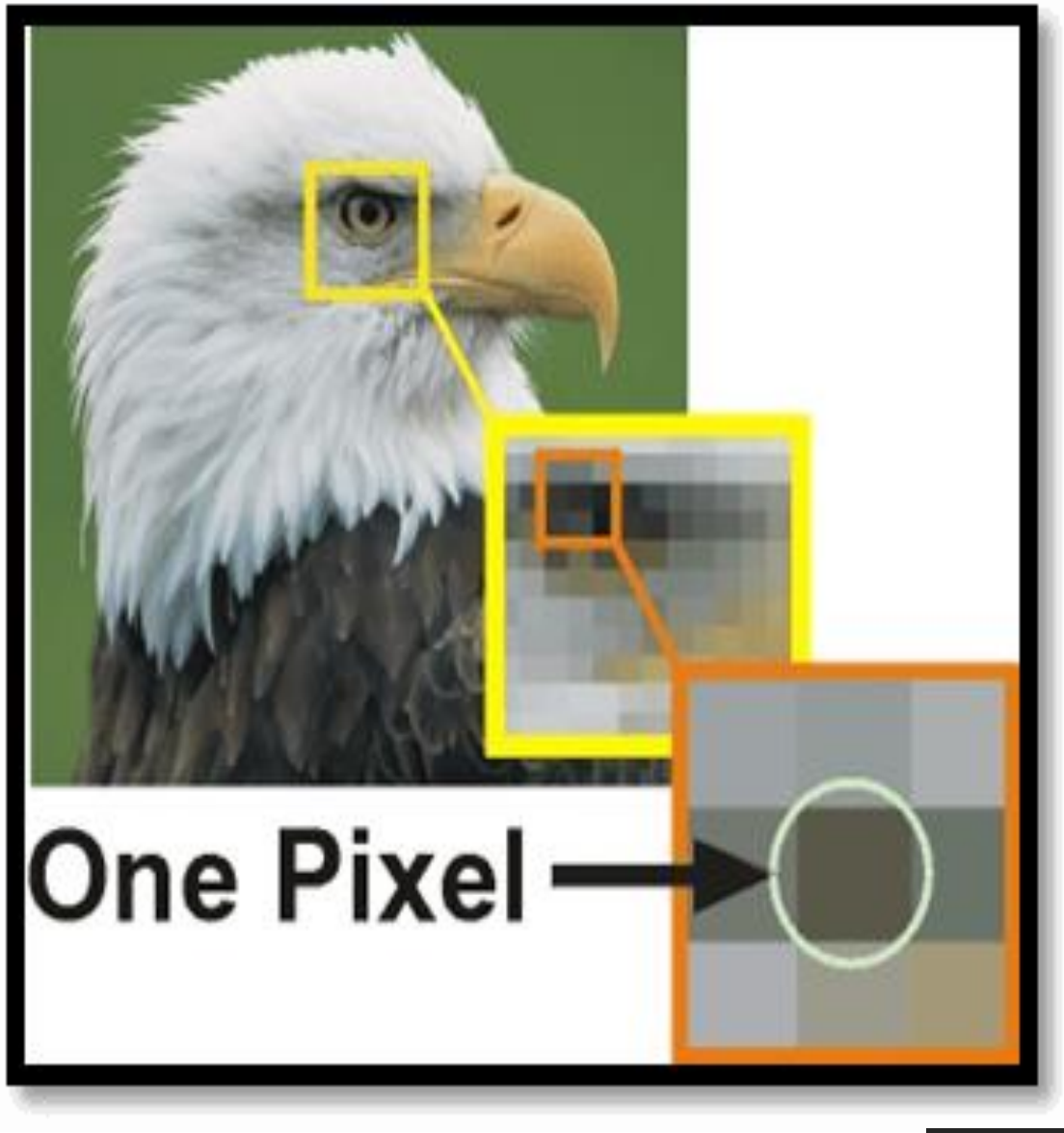


Image is defined as

- An image is formed by **two-dimensional** analog and the digital signal that contains color information arranged along x and y spatial axis.
- The value of f(x , y) at any point is gives the **pixel value** at that point of an image.
- The full form of the pixel is "Picture Element." It is also known as "**PEL**." Pixel is the smallest element of an image on a computer display, whether they are LCD or CRT monitors. A screen is made up of a matrix of thousands or millions of pixels. A pixel is represented with **a dot or a square** on a computer screen.

- The given figure is an example of digital image that you are now viewing on your computer screen. But actually , this image is nothing but a two dimensional array of numbers ranging between 0 and 255.
- There are two types of methods used for image processing namely,
    1. Analogue image processing
    2. Digital image processing

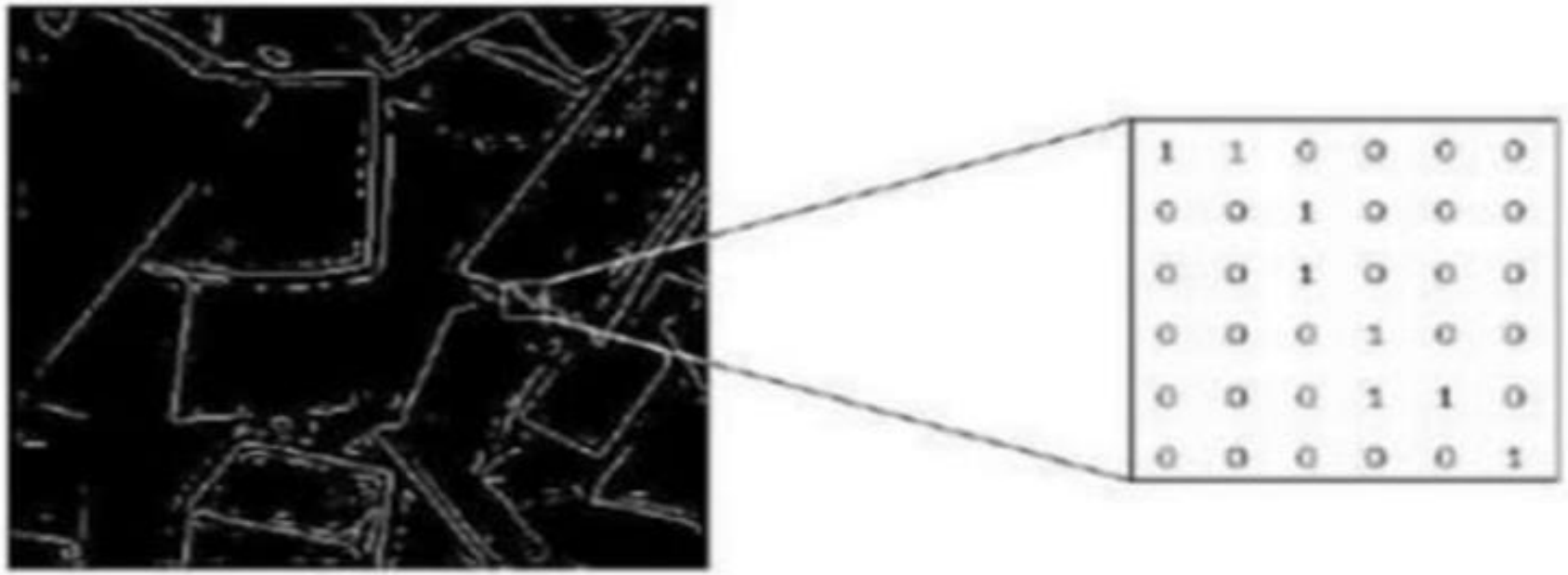


- **Analog image processing** is applied on analog signals and it processes only two-dimensional signals. The images are manipulated by electrical signals. **Examples** of analog images are television images, photographs, paintings, and medical images etc.

- **A digital image processing** is applied to digital images (a matrix of small pixels and elements). For manipulating the images, there is a number of software and algorithms that are applied to perform changes. Digital image processing is one of the fastest growing industry which affects everyone's life. **Examples** of digital images are color processing, image recognition, video processing, etc.

Binary images (Black and White)

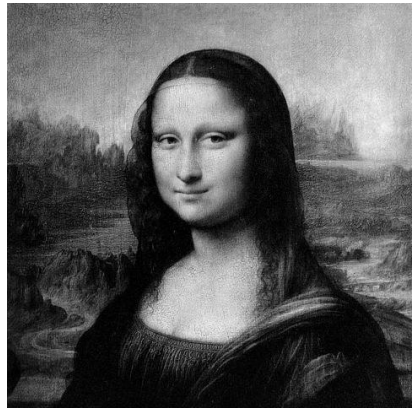
- Each pixel is just black or white
- There is only two possible values for each pixel i.e. 0 or 1



Gray-scale images

- Each pixel value of gray scale images normally from 0 (black) to 255 (white).

230	229	232	234	235	232	148
237	236	236	234	233	234	152
255	255	255	251	230	236	161
99	90	67	37	94	247	130
222	152	255	129	129	246	132
154	199	255	150	189	241	147
216	132	162	163	170	239	122

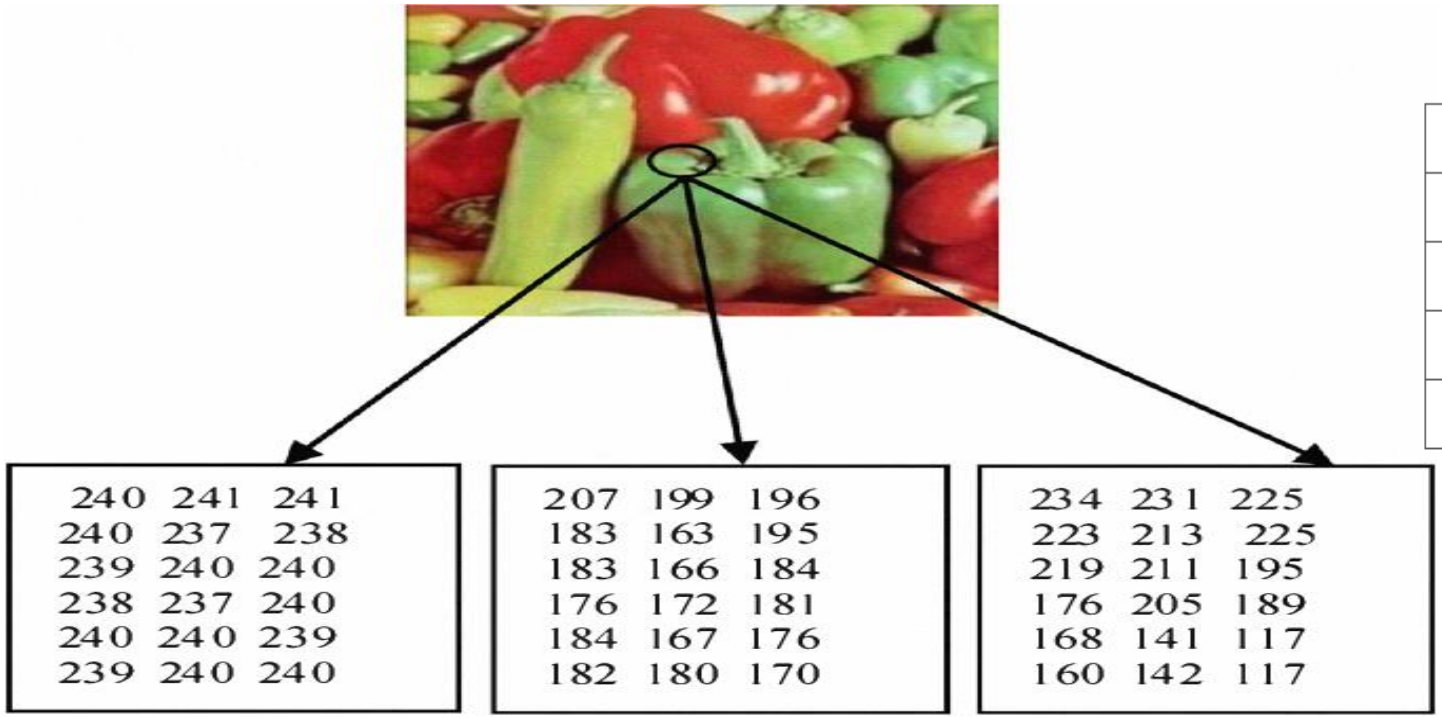


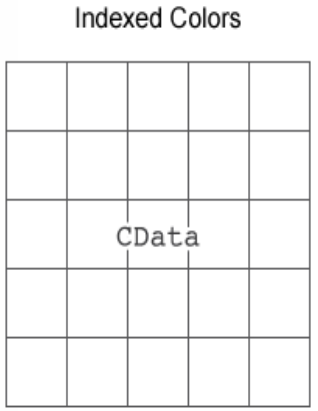
255	255	255
155	155	155
0	0	0

11111111	11111111	11111111
10011011	10011011	10011011
00000000	00000000	00000000

Color images

- In **color images** each pixel has a particular color ; that color being described by the amount of **red**, **green** and **blue** in it.
- Each of these components has a range **0 to 255**.





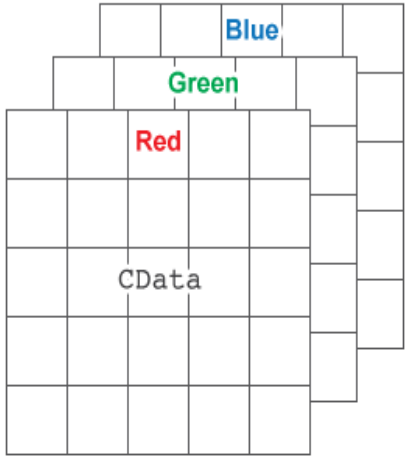


Image Noise

- Noise represents unwanted information in an image.
- Image noise is random variation of brightness or color information in the images captured.
- It is degradation in image signal caused by external sources.

$$A(x, y) = H(x, y) + B(x, y)$$

Where,

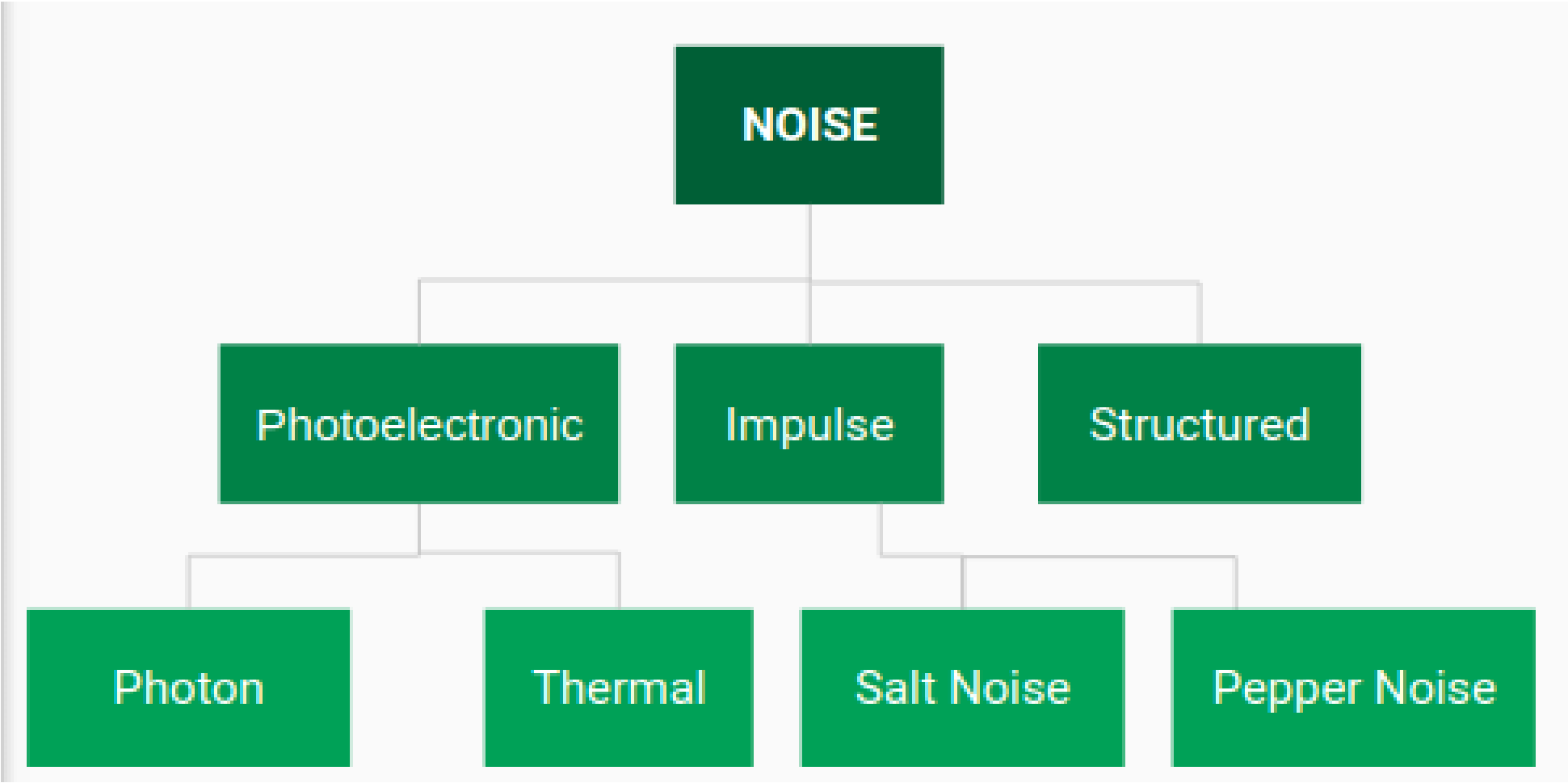
A(x , y)= function of noisy image
H(x , y)= function of image noise
B(x , y)= function of original image

Sources of Image Noise

- **Error occurs** in image signal while an image is being sent electronically from one place to another .
- **Sensor heat** while clicking an image
- **ISO factor** ISO number indicates how quickly a camera's sensor absorbs , light , higher ISO used mare chance of noticeable noise
- By memory cell failure.

Our main concern is to remove certain kind of noise. So we have to first identify certain type of noise and apply different algorithms to remove the noise.

Types of image noise

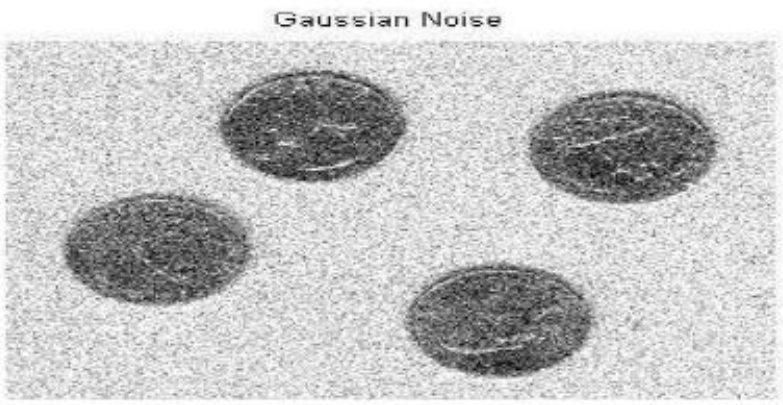


Photon/shot/Poisson Noise

- This is a type of noise connected to the uncertainty associated with the measurement of light.
- When the number of photons sensed by the sensors from the camera is not sufficient to get meaningful information from the scene photon noise arises.
- This noise occurs mostly in poor or low lighting conditions.

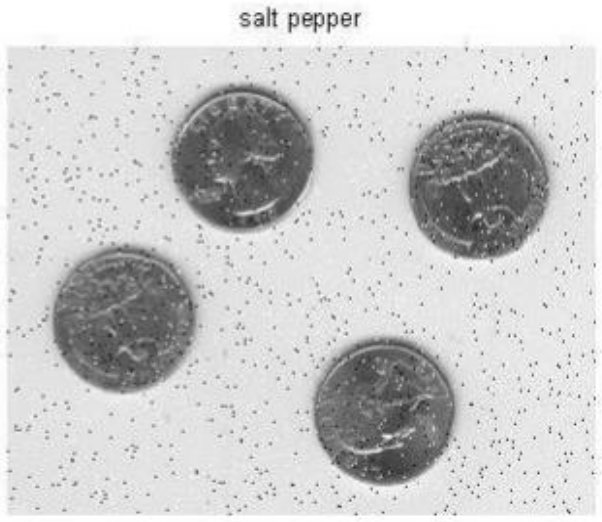
Thermal/ Johnson-Nyquist/Gaussian Noise

- Gaussian noise is evenly distributed over signal.
- This means that each pixel in the noisy image is the sum of the true pixel value and a random Gaussian distributed noise value.
- Random Gaussian function is added to Image function to generate this noise.
- The noise is independent of intensity of pixel value at each point.



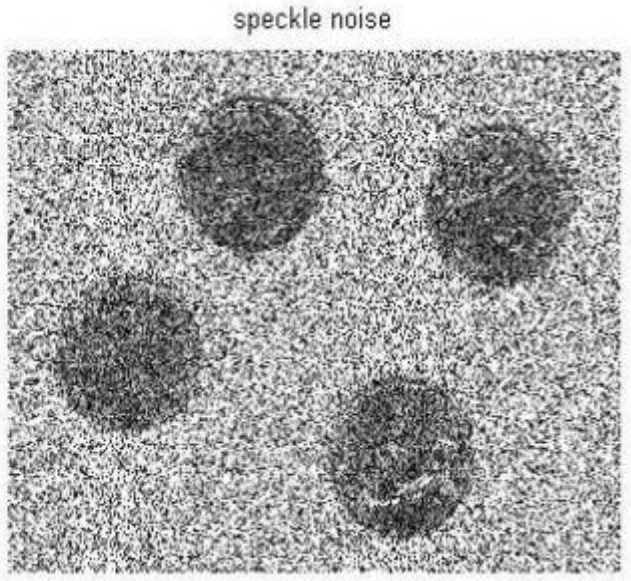
Impulse/salt and Pepper Noise

- **Salt Noise:** Salt noise is added to an image by addition of random bright (with 255 pixel value) all over the image.
- **Pepper Noise:** Salt noise is added to an image by addition of random dark (with 0 pixel value) all over the image.
- **Salt and Pepper Noise:** Salt and Pepper noise is added to an image by addition of both random bright (with 255 pixel value) and random dark (with 0 pixel value) all over the image.



Speckle Noise

- Speckle noise can be generated by multiplying random pixel values with different pixels of an image.
- P = I + n * I Where P is the speckle noise distribution image, I is the input image and n is the uniform noise image by mean o and variance v.
- Speckle is a granular noise that inherently exists in an image and degrades its quality.



Removal of Noise from Images

- Image de-noising is very important task in image processing for the analysis of images.
- One goal in image restoration is to remove the noise from the image in such a way that the original image is discernible.
- Image de-noising is often used in the field of photography or publishing where image was somehow degraded but needs to be improved before it can be printed.
- There are two types of noise removal approaches

1. Linear Filtering
2. Non Linear Filtering

Linear Filtering:

- Linear filters are used to remove certain types of noise.
- These filters remove noise by convolving the original image with a mask filters also tend to blur the sharp edges, destroy the lines and other fine details of the image

Non-Linear Filtering:

- Non- linear filter is a filter whose output is not a linear function of its inputs.
- The general idea in non-linear image filtering is that instead of using the spatial mask in a convolution process, the mask is used to obtain the neighboring pixel values, and then ordering mechanisms produce the output pixel.

Different types of linear and non-linear filters:

- Mean Filter
- Median Filter
- Adaptive Filter
- Gaussian Filter
- Weinier Filter

Noise	Best Suited Filters
Salt and Pepper	Median
Poisson	Mean
Gaussian	Gaussian
Speckle	Weinier

Image Enhancement

- Image enhancement is the process of adjusting digital images so that the results are more suitable for display or further image analysis. For example, you can remove noise, sharpen, or brighten an image, making it easier to identify key features.
- Here are some useful examples and methods of image enhancement:

  Filtering with morphological operators

  Histogram equalization

  Noise removal

- Image enhancement algorithms include de-blurring, filtering, and contrast methods

Deblurring images using a Wiener filter.

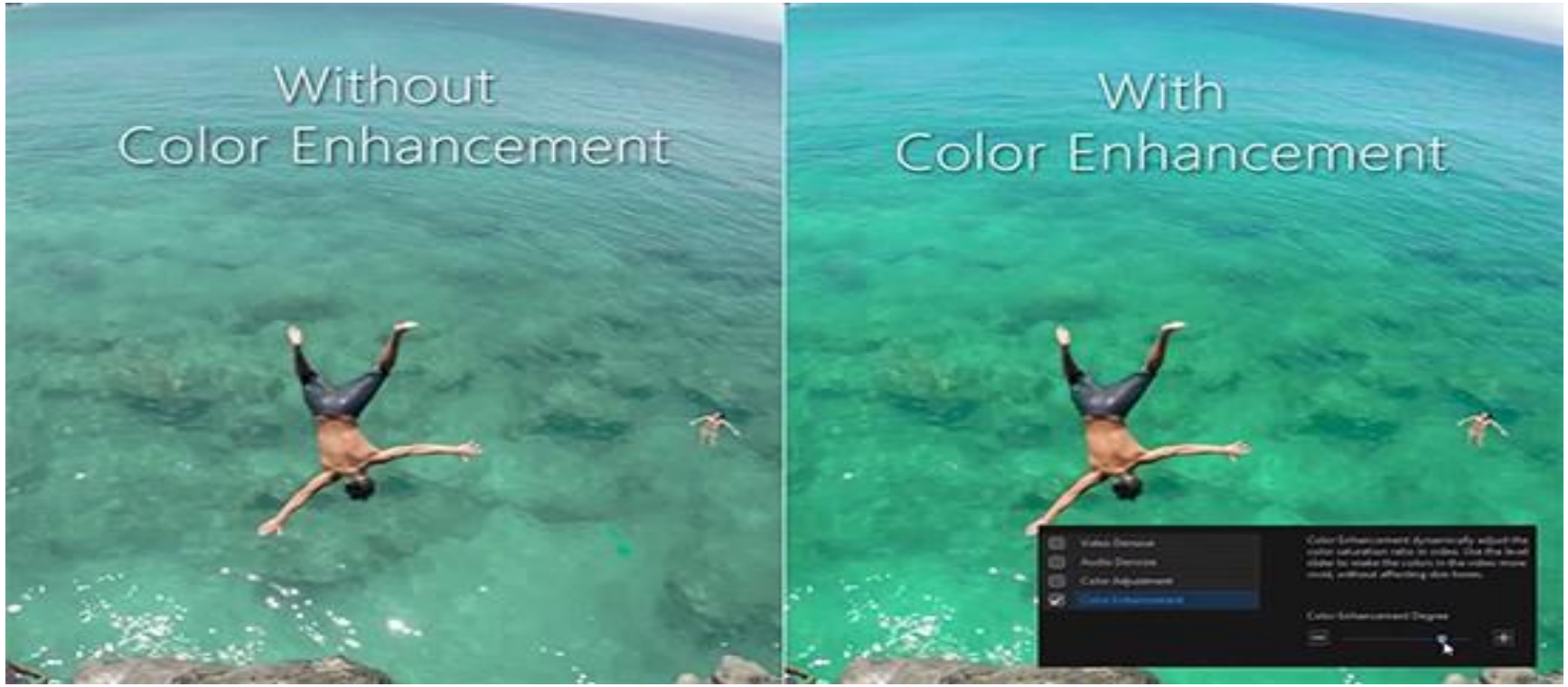
Contrast Enhancement

Original image with low contrast

Enhanced image

Color Enhancement

- **Color enhancement** refers to any type of process or treatment that modifies or enhances the **color** of a natural image.



Color Enhancement can be done by adjusting the red/green/blue values for a pixel as follows:

1. find the maximum of the three input values
2. scale RGB values downward by taking a power of their fraction of this maximum.
3. Multiply the result value maximum of three input values

So, for instance, if the three values are

red: 140 green: 105 blue: 201

the "enhancement factor" is 2.0, then

Red -> ((140/201)^2.0) * 201 = 97
Green -> ((105/201)^2.0) * 201 = 55
Blue -> ((201/201)^2.0)* 201 = 201

and the pixel goes from somewhat blue to very blue.
The visual affect is to "enhance" the color without changing very much the perceived intensity.

Segmentation

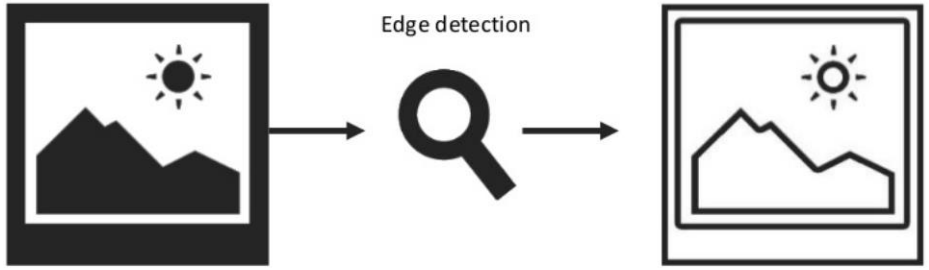
- **Image segmentation** is the process of partitioning a digital image into multiple segments (sets of pixels, also known as image objects).
- The goal of segmentation is to simplify and/or change the representation of an image into something that is more meaningful and easier to analyze.

Some of the practical applications of image segmentation are:

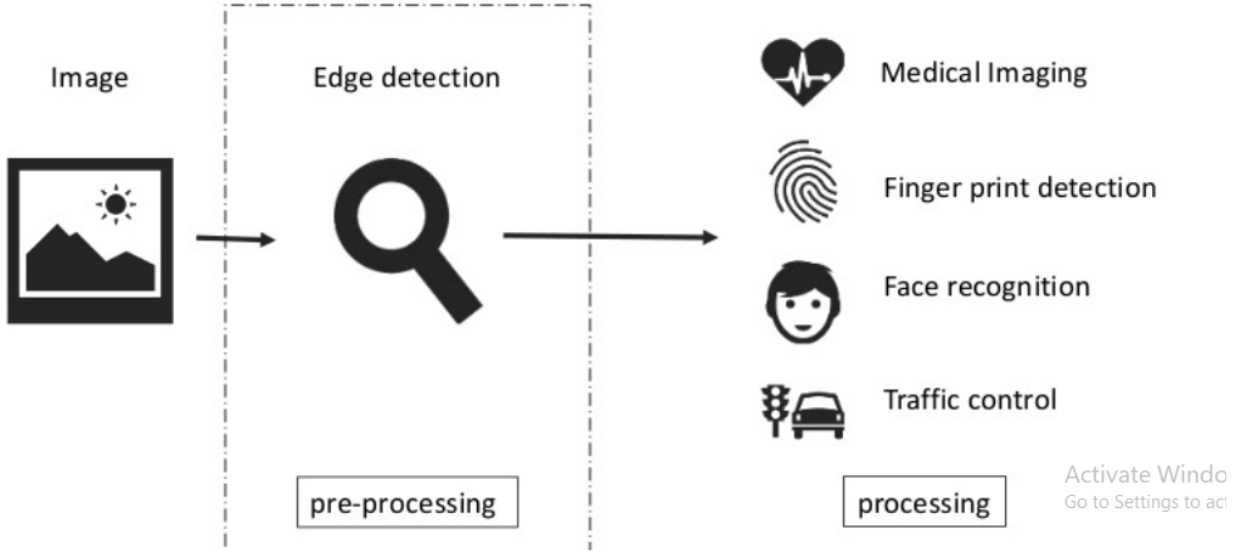
- Object detection
  - Pedestrian detection
  - Face detection
  - Brake light detection
  - Locate objects in satellite images (roads, forests, crops, etc.)
- Recognition Tasks
  - Face recognition
  - Fingerprint recognition
  - Iris recognition
- Traffic control systems
- Video surveillance
- Video object co-segmentation and action localization

Edge Detection

- Edge detection is the process of finding the set of pixels that represent the boundary of disjoint regions in an image.



- Edge detection is important for image segmentation, since many image processing algorithms are first required to identify the objects and then process them.



Edge Detection Usage

- Reduce unnecessary information in the image while preserving the structure of the image.
- Extract important features of an image
  - Corners
  - Lines
  - Curves
- Recognize objects, boundaries, segmentation.
- Part of computer vision and recognition.

Optical Character Recognition

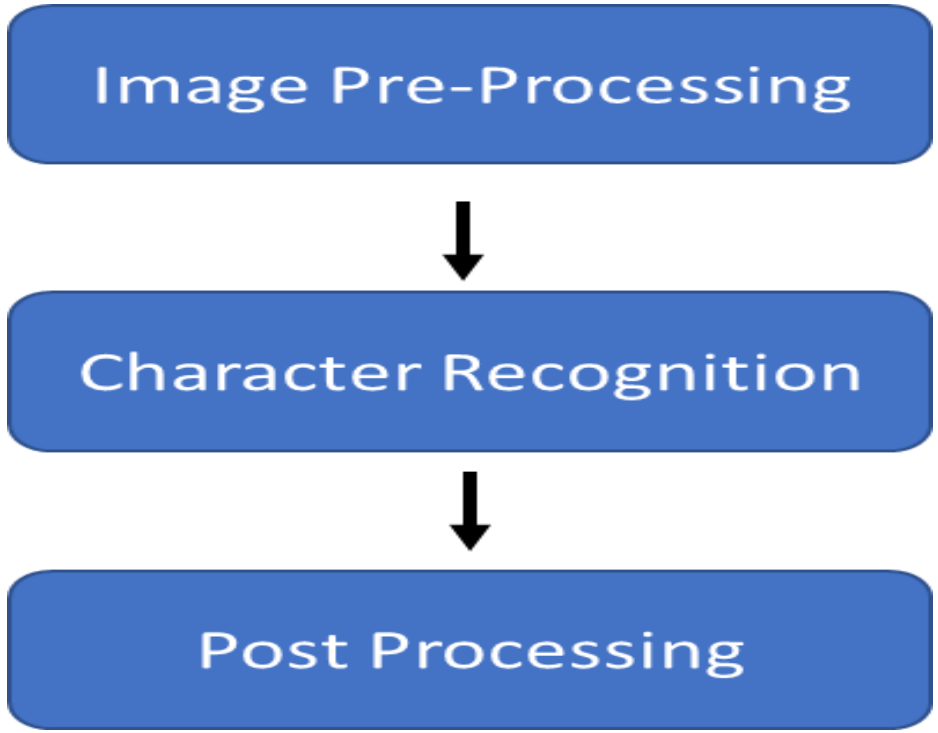
- Optical Character Recognition (OCR) defines the process of mechanically or electronically converting scanned images of handwritten, typed or printed text into machine-encoded text.
- It will learn and recognize the letters, but not the meaning of the word.

WHAT IS OCR TECHNOLOGY?

- OCR technology deals with the problem of recognizing all kinds of different characters.
- Both handwritten and printed characters can be recognized and converted into a machine-readable, digital data format.

Three basic steps of optical character recognition(OCR)

- **Step 1:** Image Pre-Processing in OCR
- **Step 2:** Character Recognition in OCR
- **Step 3:** Post-Processing in OCR



Step 1: Image Pre-Processing in OCR

- OCR software often pre-processes images to improve the chances of successful recognition.
- The aim of image pre-processing is an improvement of the actual image data.
- In this way, unwanted distortions are suppressed and specific image features are enhanced.

Step 2: Character Recognition in OCR

- For the actual character recognition, it is important to understa
- When the input data is too large to be processed, only a reduce
- The features selected are expected to be the important ones w be redundant are ignored.
- For the process of OCR, the algorithm has to detect specific p image or video stream.

Step 3: Post-Processing in OCR

- Post-processing is another error correction technique that ensures the high accuracy of OCR.
- The accuracy can be further improved if the output is restricted by a lexicon.

Applications of OCR:

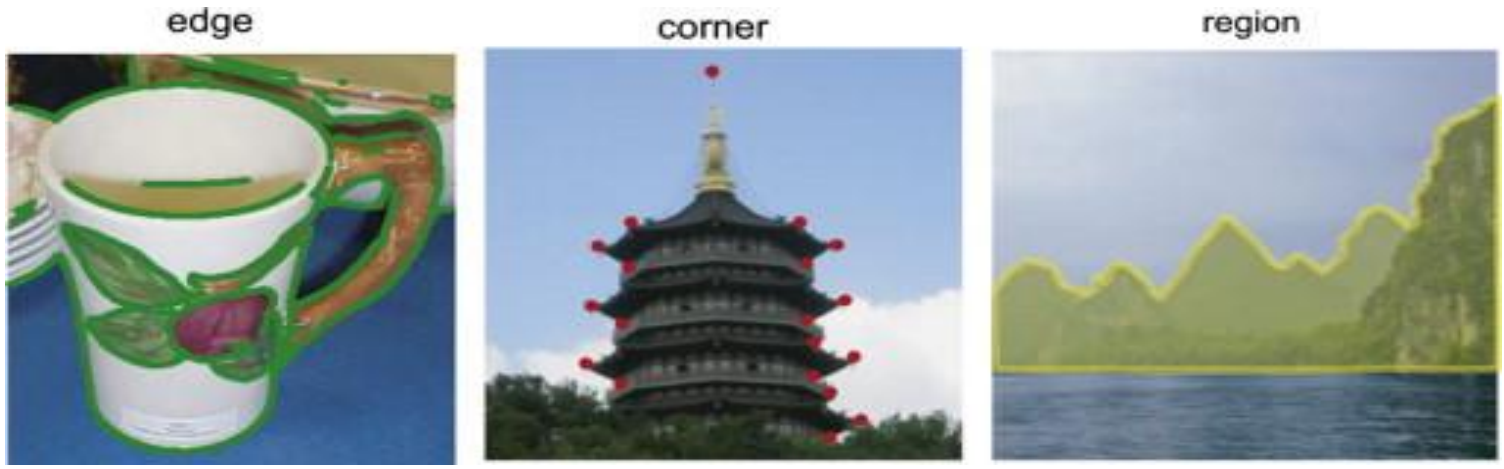
- Identification Processes
- Payment Processes
- License Plate Scanning
- Passport /Driver's License Scanning
- Serial Number Scanning
- Document Scanning
- Vehicle Identification Number Scanning
- Barcode Scanning

Feature Detection

- In computer vision and image processing **feature detection** includes methods for computing abstractions of image information and making local decisions at every image point whether there is **an image feature** of a given type at that point or not.
- The resulting features will be subsets of the image domain, often in the form of isolated points, continuous curves or connected regions.

Definition of Feature:

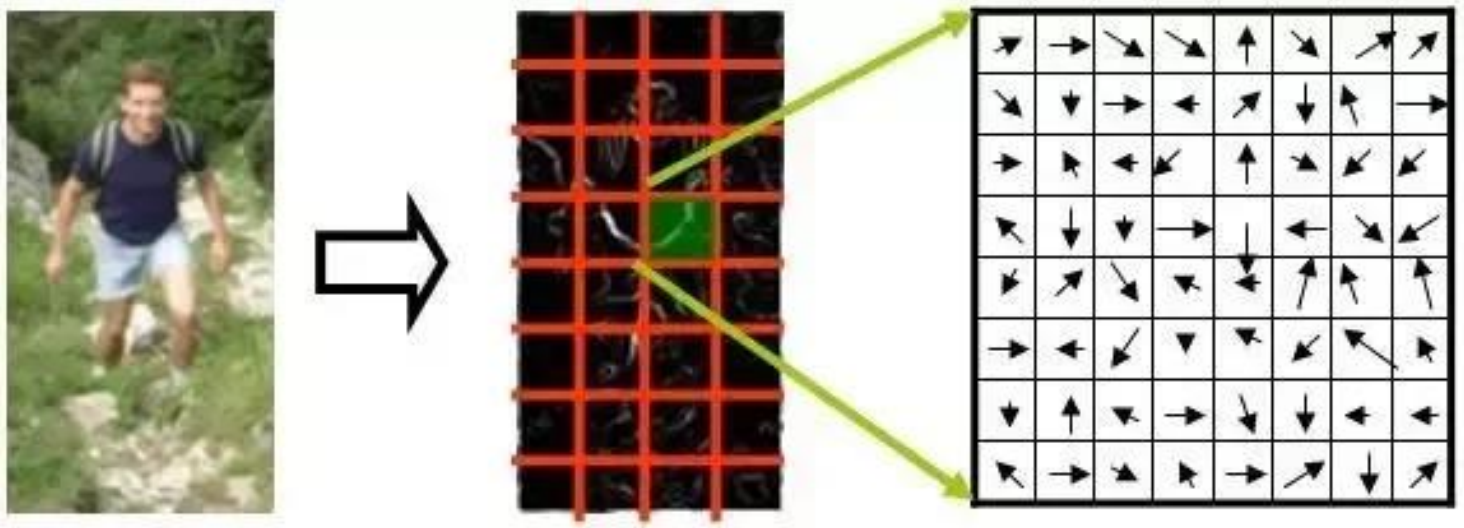
- a feature is typically defined as an "**interesting**" part of an image, and features are used as a starting point for many computer vision algorithms.



Main Component of Feature Detection

Detection: Identify the **Interest Point**

Description: The local appearance around each feature point is described in some way that is (ideally) invariant under changes in illumination, translation, scale, and in-plane rotation. We typically end up with a descriptor vector for each feature point.



Types of Image Features:

1. Edges

- Edges are points where there is a boundary (or an edge) between two image regions.
- In general, an edge can be of almost arbitrary shape, and may include junctions. In practice, edges are usually defined as sets of points in the image which have a strong gradient magnitude.
- Locally, edges have a one-dimensional structure.

2. Corners / interest points

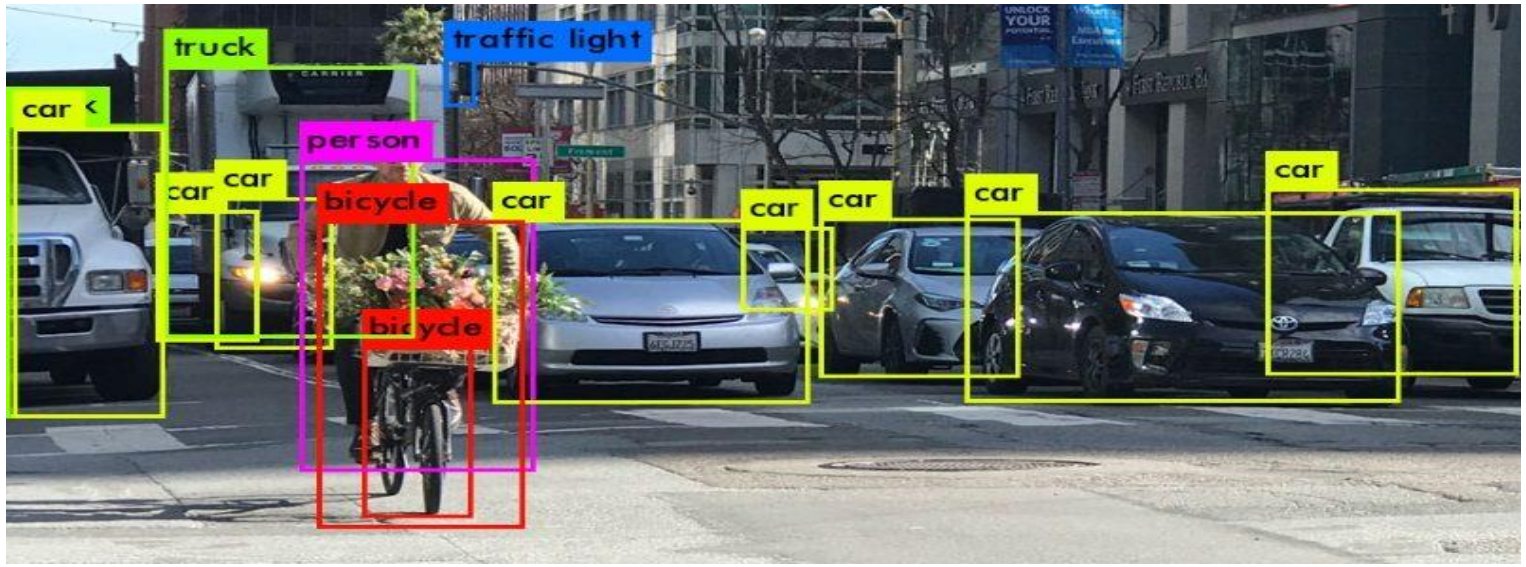
- The terms corners and interest points are used somewhat interchangeably and refer to point-like features in an image, which have a local two dimensional structure.
- The name "Corner" arose since early algorithms first performed edge detection, and then analysed the edges to find rapid changes in direction (corners).

3. Blobs / regions of interest points

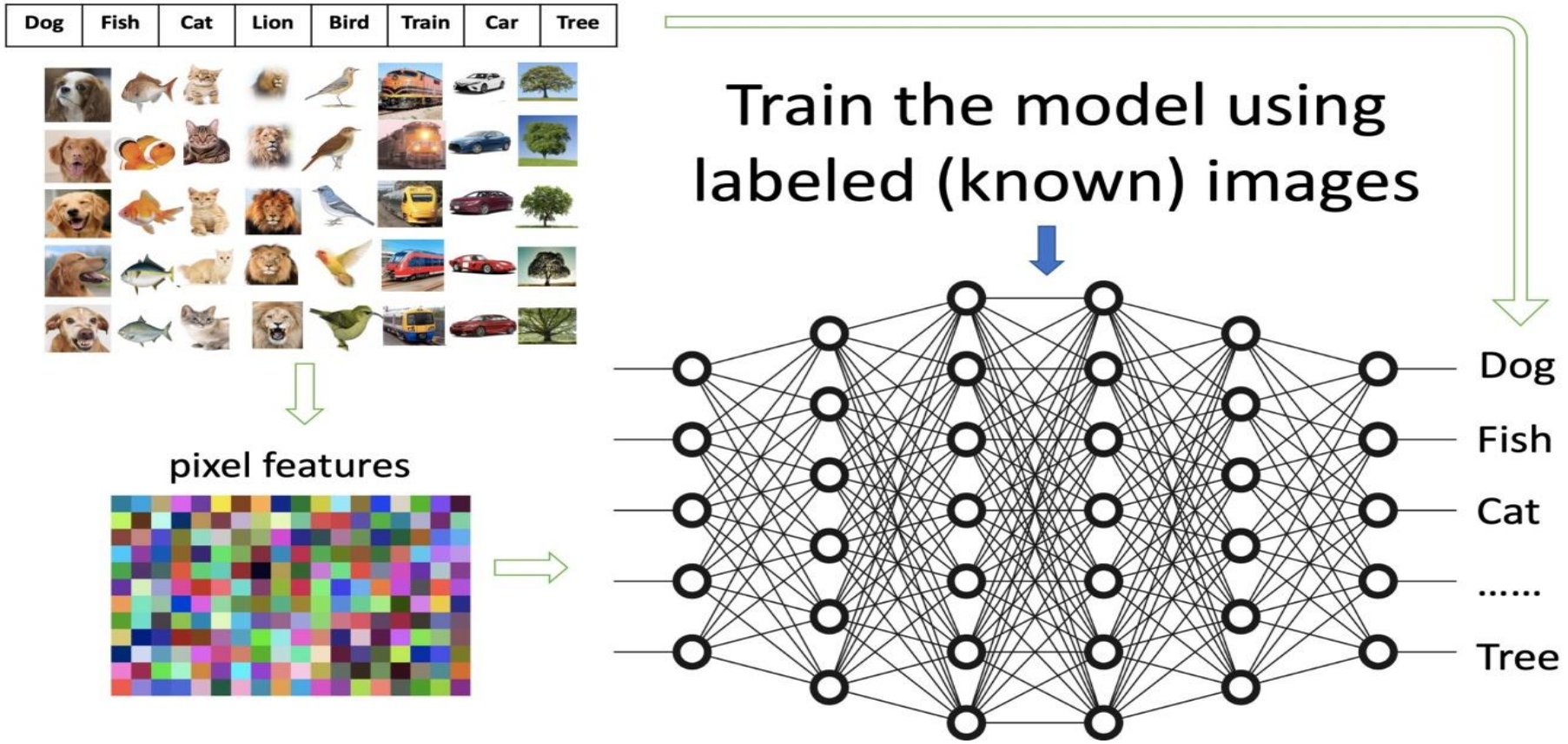
- Blobs provide a complementary description of image structures in terms of regions, as opposed to corners that are more point-like.
- Nevertheless, blob descriptors may often contain a preferred point (a local maximum of an operator response or a center of gravity) which means that many blob detectors may also be regarded as interest point operators.
- Blob detectors can detect areas in an image which are too smooth to be detected by a corner detector.

Recognition

- **Image recognition** is the ability of a system or software to identify objects, people, places, and actions in images.
- It uses machine vision technologies with artificial intelligence and trained algorithms to recognize images through a camera system.
- While human and animal brains recognize objects with ease, computers have difficulty with the task. Software for image recognition requires deep machine learning. Performance is best on Convolutional Neural Network (CNN) processors.



- Google, Facebook, Microsoft, and Apple are among the many companies that are investing significant resources and research into image recognition and related applications.



Save Trees

And

Save Power