1 Introduction to Image Processing And Analysis

1.1 The subject of Image Processing And Analysis

Image Processing And Analysis is an interdisciplinary scientific field that deals with how computers can gain high-level understanding from digital images or videos. From the perspective of engineering, it seeks to understand and automate tasks that the human visual system can do (In correspondence with the Wikipedia).

The Image Processing And Analysis as a rule includes a several typical tasks:

1. **Image classification** Give a label to an image, or in other words, "understand" what is in an image.
2. **Classification and localization** Give a label to an image and determine the borders of the object contained in it (and typically draw a rectangle around the object).
3. **Object detection**: The task to determine all the instances of several objects (for example, people, cars, signs, etc.) and draw bounding rectangle boxes around them.

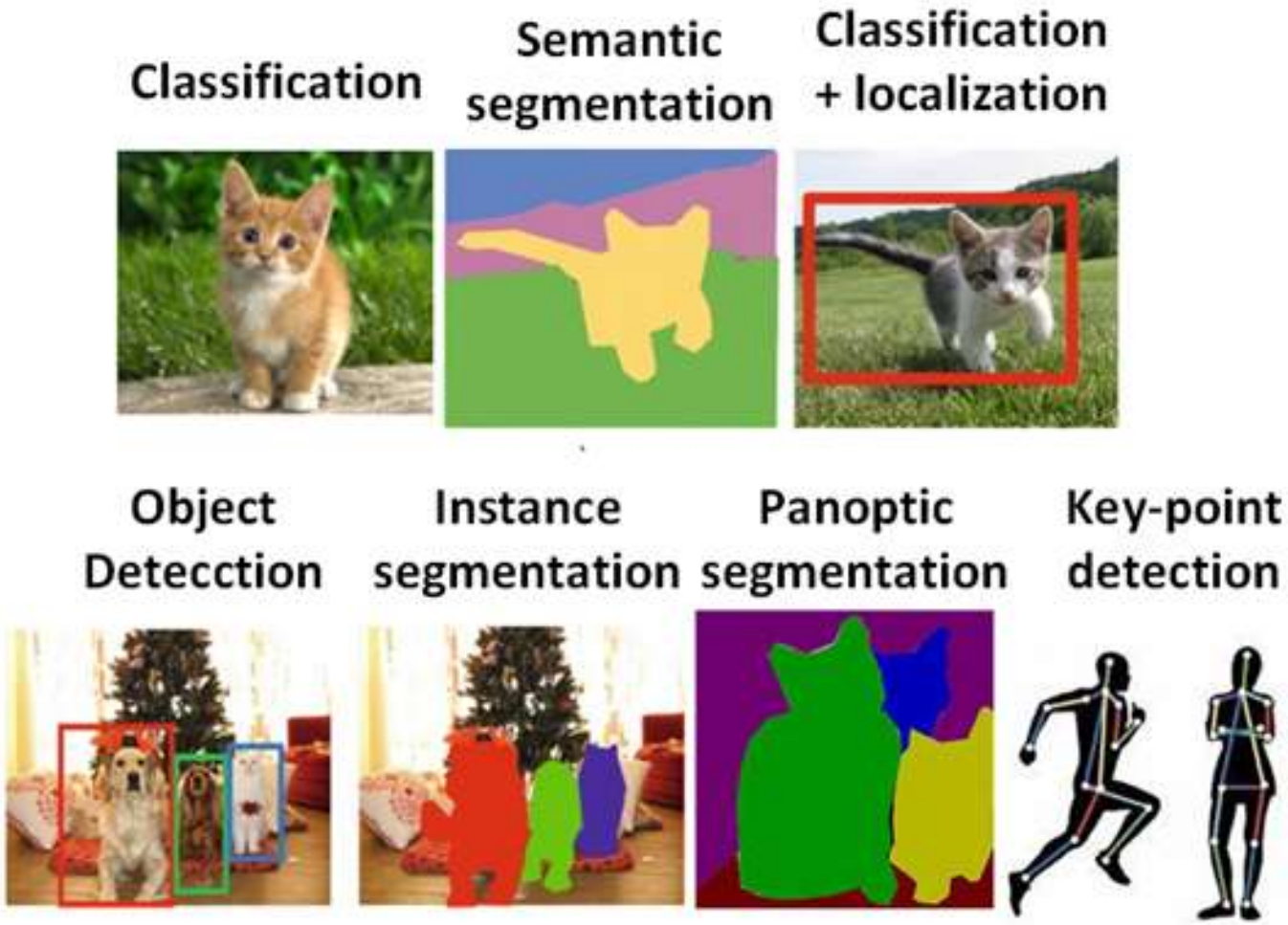
4. **Semantic segmentation** : The task to label each pixel of the image with a specific class. All pixels belonging to one class will be labelled in one color.

   In instance segmentation, you will still be able to tell how many instances of a car you have and where they are exactly.

5. **Instance segmentation** :The task to label each pixel of the image with a specific class for each separate instance, to be able to find the exact limits of the object instance.
6. **Panoptic segmentation** :The task is to join semantic segmentation (all picture segmentation) and Instance segmentation together.
7. **key-point detection** :The task to find and determine a set of specific points to make some classification of action or object (for instance, key-point face recognition, object landmark detection).

Notes:

- Under the image first we considering 2-d objects, however it can be 3-d and any other also.
- Beside the previously pointed tasks there are can be such tasks as:
  - Image reconstruction.
  - Image style change.
  - Image generation.
  - Image annotation.
  - Image suppression (compression)/image quality improvement /super resolution.



In addition to image processing the video processing tasks include:

1. **video understanding** the task is to classify and localise (in space and time) different events appearing in the video.
2. **object tracking** the task us to creating a unique ID for each of the initial detections, and then tracking each of the objects around frames in a video, maintaining the ID assignment.
3. **action recognition** the task is to recognize and localise (in space and time) different actions in the video.
4. **video prediction** the task is to predict the following behavior of object based on the video frame.
5. **Scene based creates a 3D model** of a scene inputted through images or video.
6. **In image reconstruction by video scene**,and denoising.

Note: In fact all methods of video processing based on the image processing.

Example of video object tracking.

1.2 Examples of Image Processing And Analysis Applications

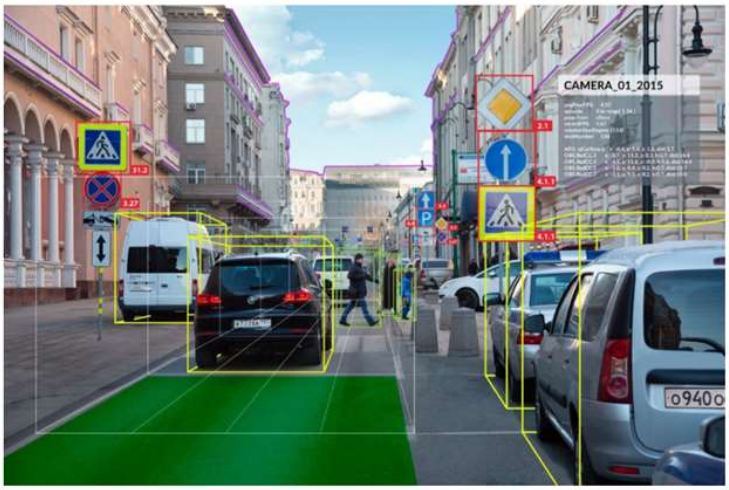
Some **practical applications of computer vision systems** are:

- Face recognition.
- Autonomous vehicles (self-driving cars).
- Autonomous manufacturing product control.
- Autonomous safety control.
- Improved image and video searching (retrieval searching).
- Medical Diagnostic.
- Internet of things.

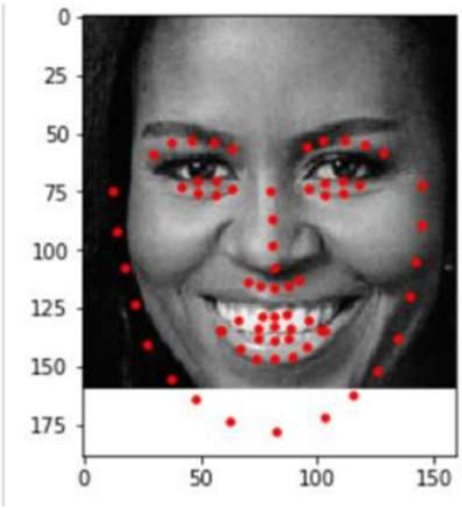
Other interesting applications

- Image and video generation.
- Image and video resolution increasing.
- Image and video upscaling and quality improvement.
- Image and video description.
- Image and video colorization.
- Image and video style transfer.

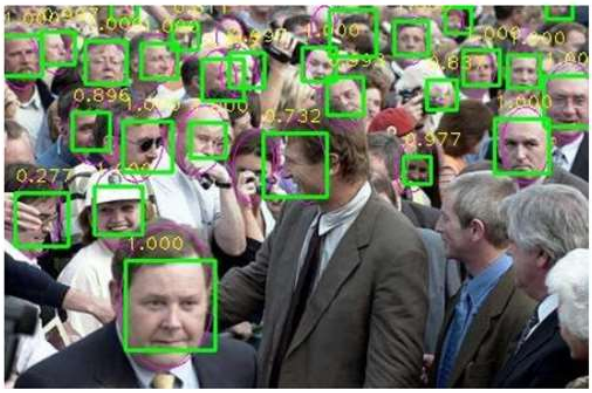
Self-Driving Cars



Key-point face recognition

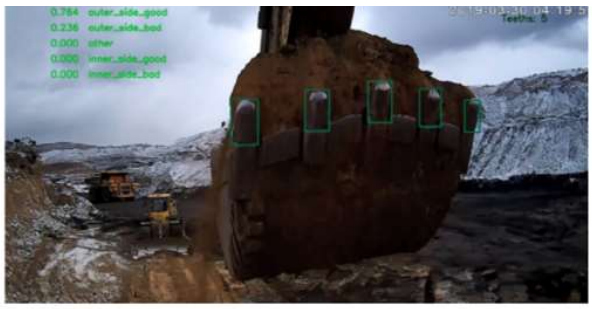


counting the number of people in crowd

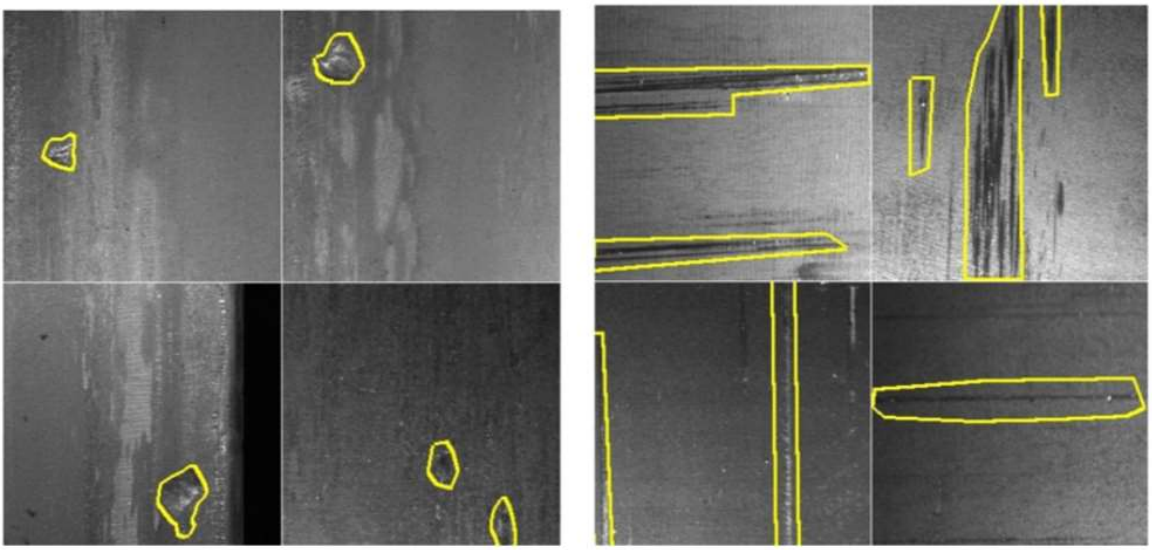


Autonomous industrial safety control.

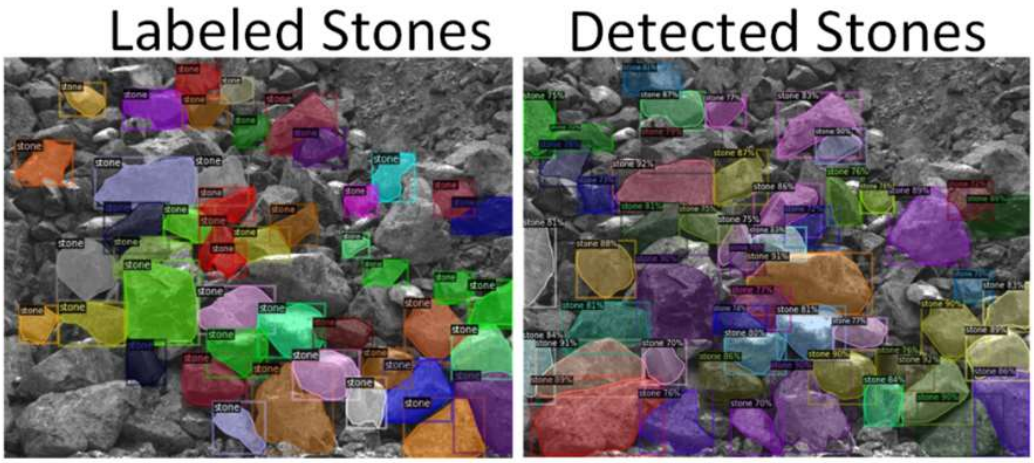
Monitoring systems for bucket excavator teeth state.



Non-destructive testing of metal defects



Autonomous stones selection and camera aiming for mining company



Autonomous car number recognition

Old equipment digitalisation.

Stone breaks detection (healthcare).

Autonomous parking lot classification

Counting and estimating the size of pipes at each stage of the logistics process.

Disease diagnostic.

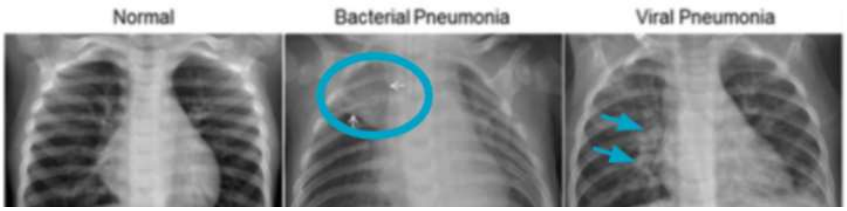
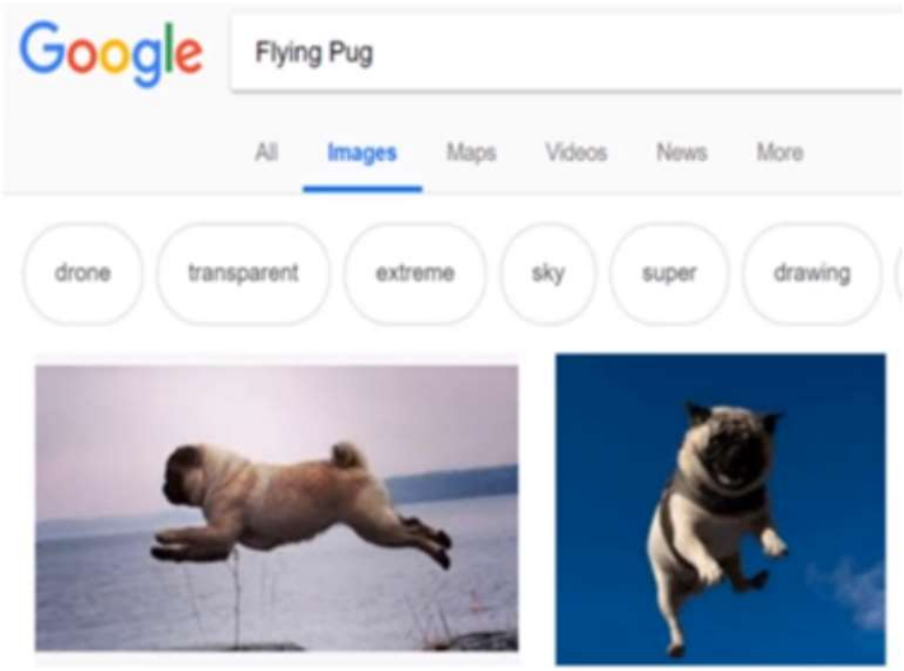


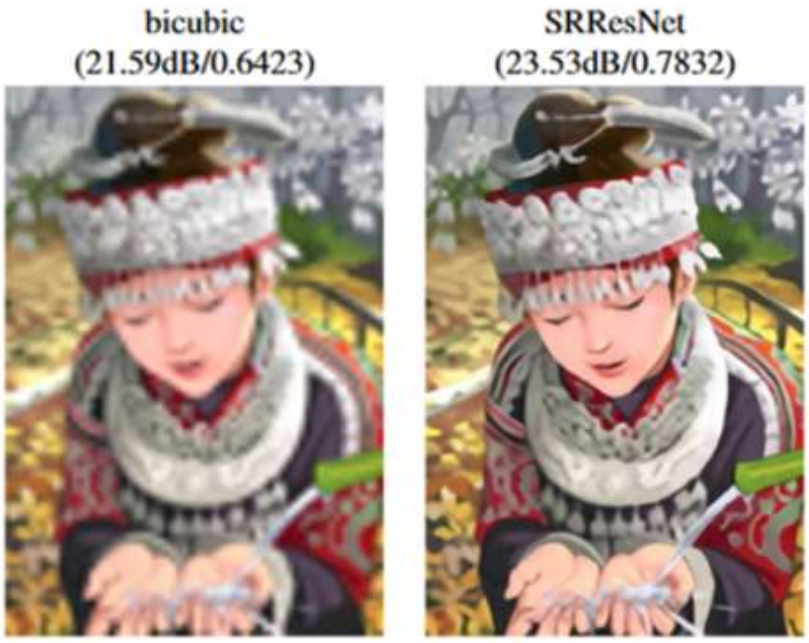
Image and video searching



Shopping helper (Internet of things application).

Other interesting applications

Image conventional upscaling (bicubic) and super-resolution upscaling



Example Image-to-Image translation

Example Image colorization

Style transfer

Image reconstruction

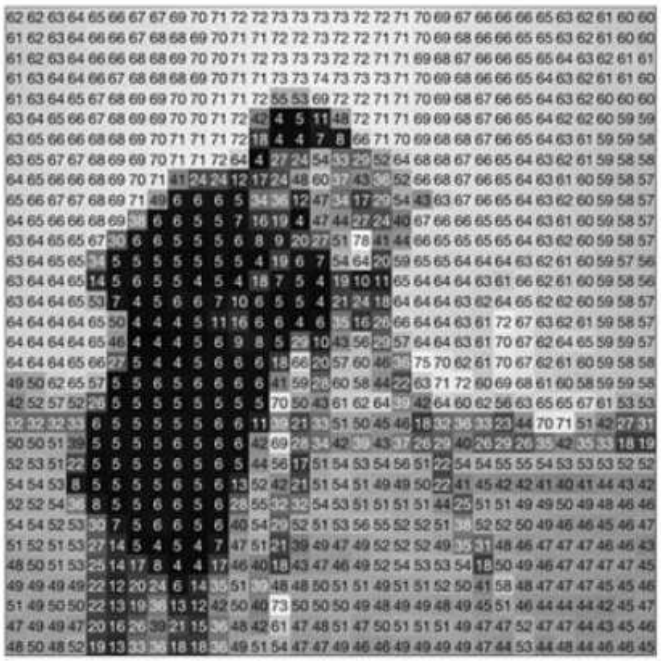
Automatic Image description

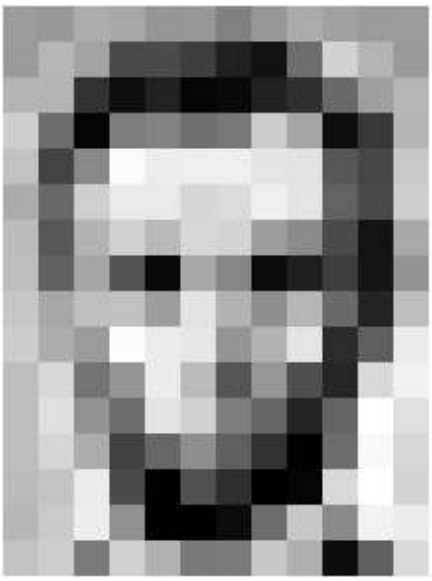
Image and scene generation

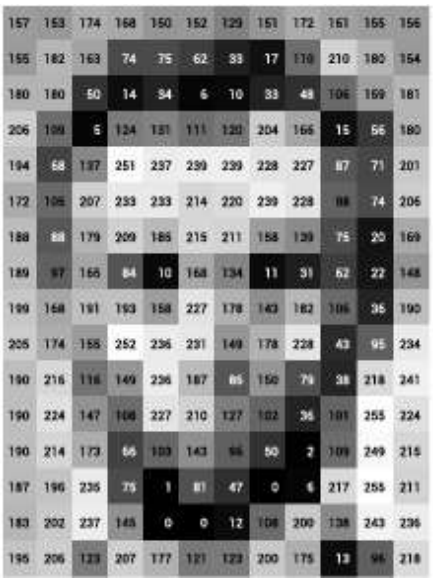
1.3 Methods of Image Processing And Analysis

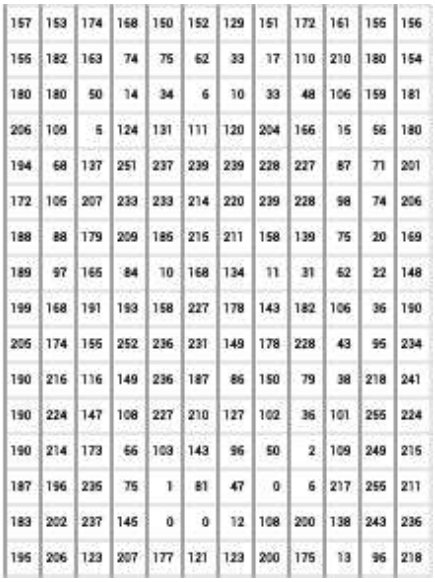
From digital point of view each **image (in gray sclae)**

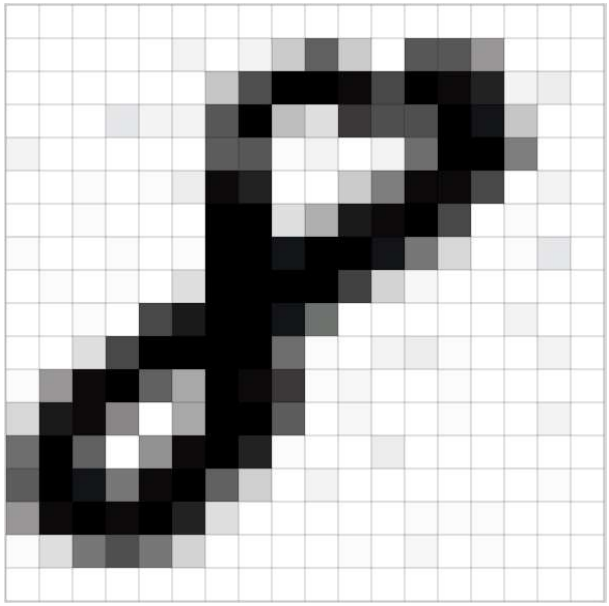
can be represented as a set of digits.





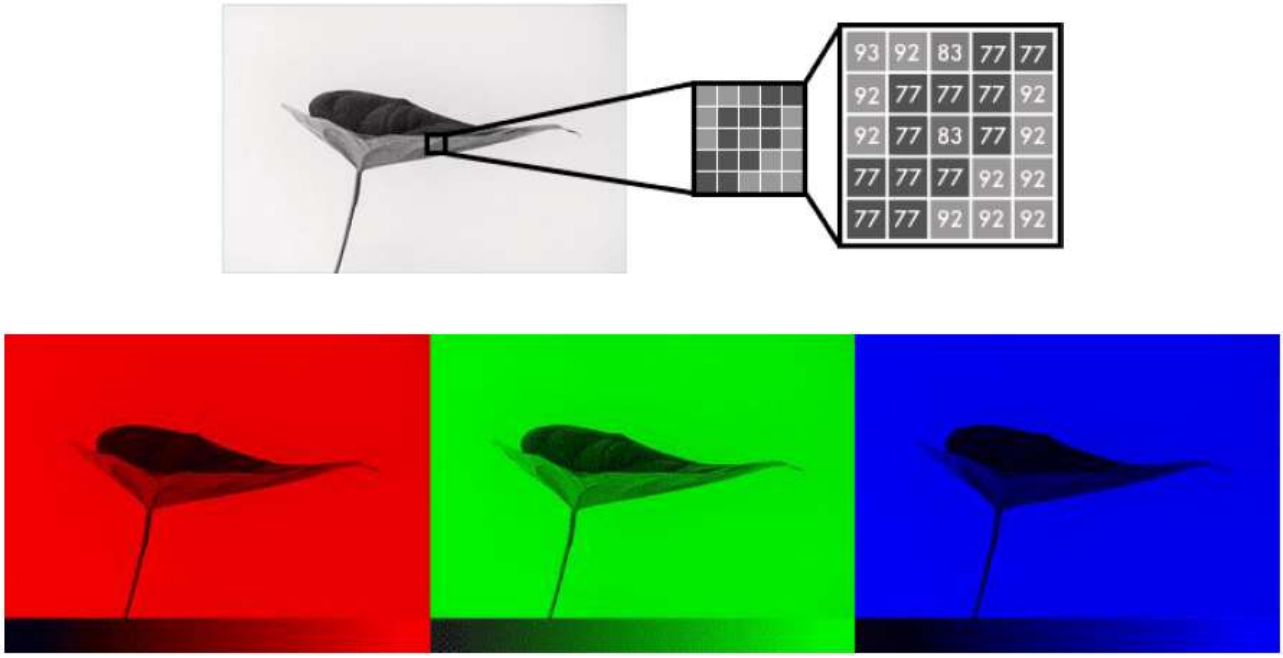






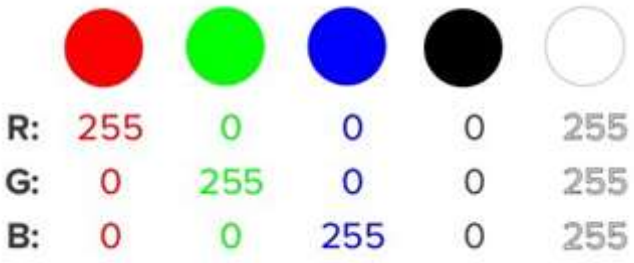
If we have an color imgae it can be represented as three:

Red, Green and Blue (RGB) matrices joined together in so-called tensor.



As a rule each color have gradation from 0 to 255.

For instance,



There are exist a lot of approaches for solving computer vision problems, such

as:

- **Statistical approaches** (work with the image as with multi-dimension stochastic samples e.g. histogram of values(colors), threshold, optimal filtration).
- **Classical digital-filters based approaches** (work with image as with multi-dimension digitized signal: e.g. blurring, contrasting, edges highlighting, geometrical contours searching).
- **Classical machine learning** (work with the image as with set of data (or features), for which, as rule, performing manual feature extraction, and then e.g. SVM, tree-based, and e.t.c.).
- **Deep learning neural networks** (work with the image as with multi-dimension set of data with automatically feature extraction and processing).

Among the all methods of computer vision -
Deep learning convolution neural networks (CNN)
is the most popular and the most applicable up-to-date.

Example: Edge Detection based on the color threshold.

Example: Noise reduction using mean, median and gauss filter.

Ground truth Image

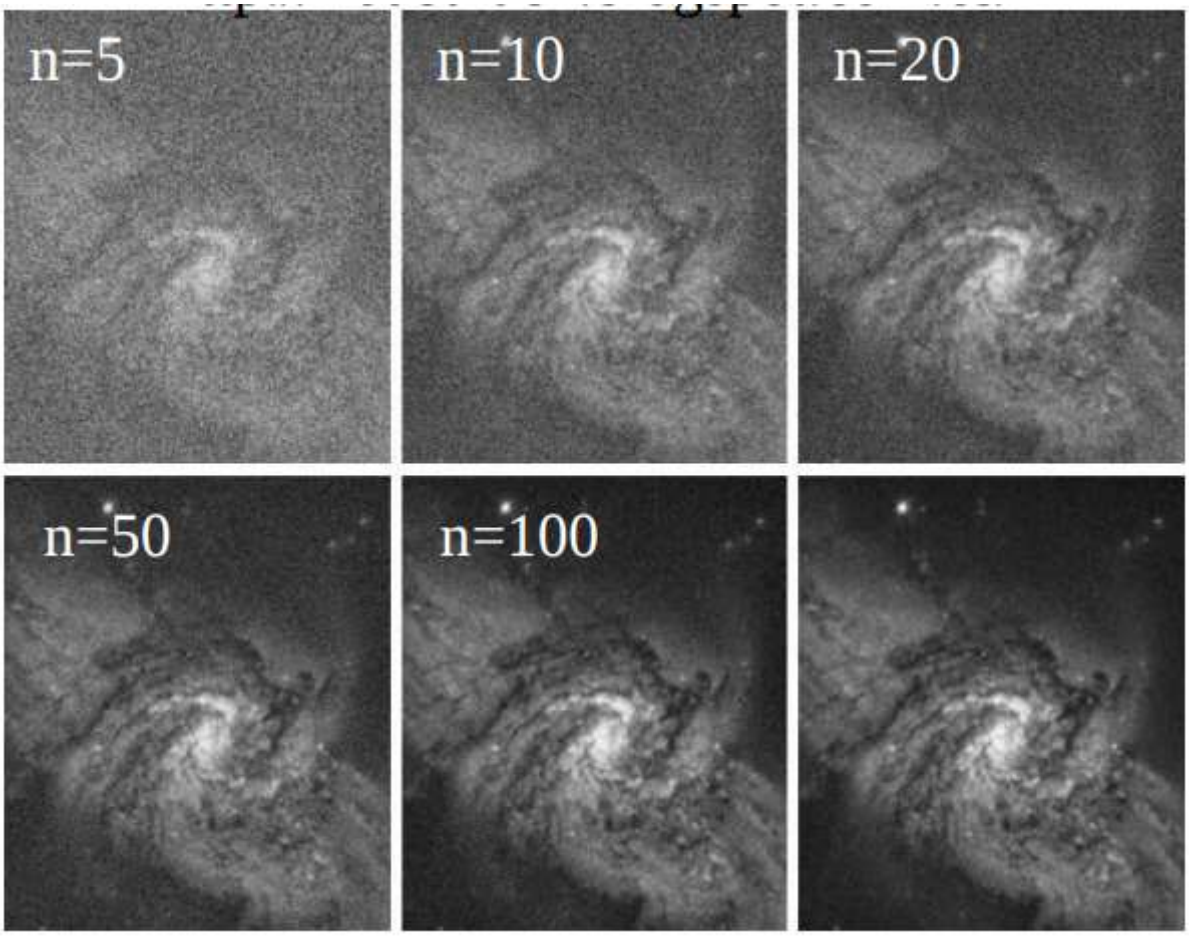
Noised Image

Median filter

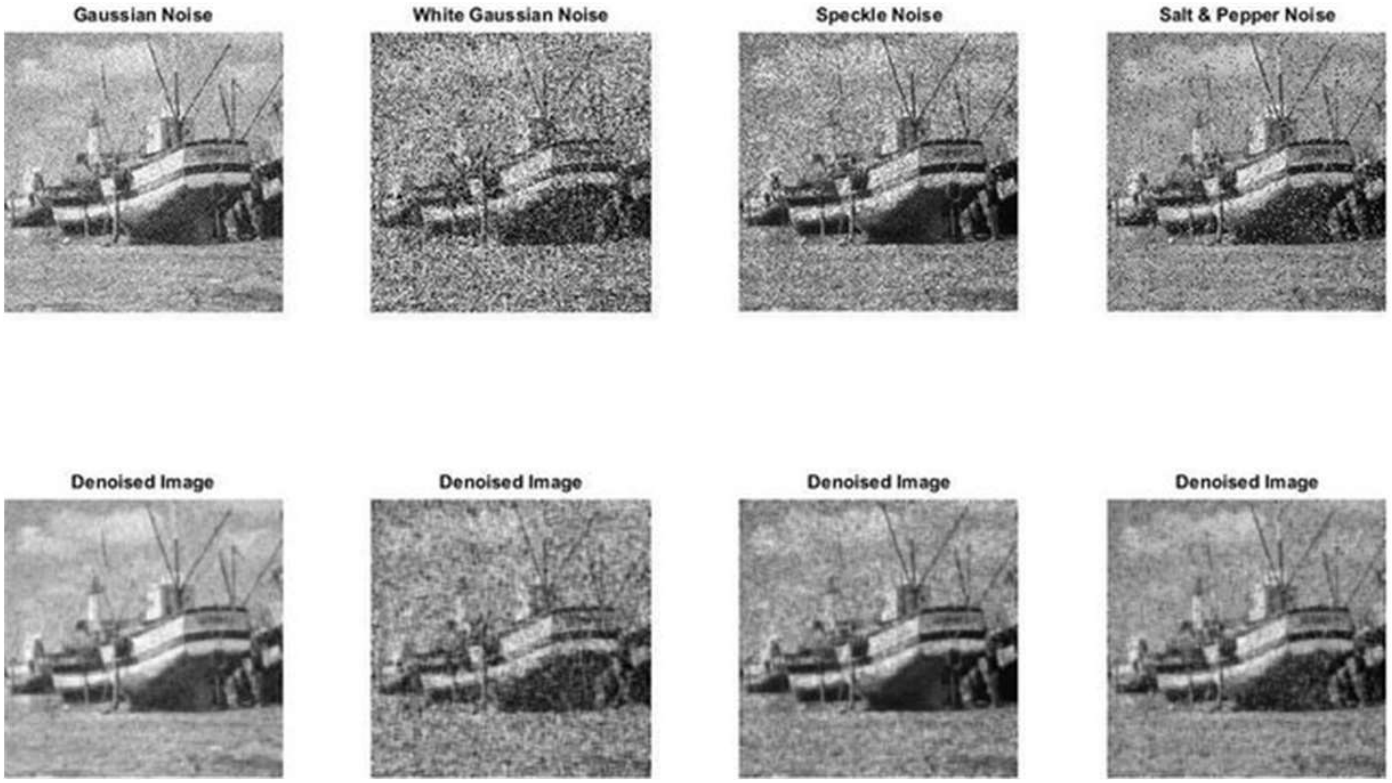
Mean filter

Gaussian filter

Example image denoising by several images averaging for Astronomical telescope images.



Example: Noise reduction (de-noising) using Gauss-Blurring for different types of noises.


Gaussian Noise
White Gaussian Noise
Speckle Noise
Salt & Pepper Noise
Denoised Image
Denoised Image
Denoised Image
Denoised Image

There can be a several types of noises in images:

- **Gaussian Noises**:

  Gaussian noise is statistical noise which values are Gaussian-distributed.

  Principal sources arise during acquisition e.g. sensor noise caused by poor illumination and/or high temperature, and/or transmission e.g. electronic circuit noise

  - **White Gaussian noise**: A special case where the any pair of values at any are identically distributed and statistically independent (and hence uncorrelated).

- **Salt-and-pepper noise** is a form of noise presents as sparsely occurring white and black pixels.

  This noise can be from different sources in camera, e.g., by defects in the camera matrix or in the transmission track of the image.

- **Shot noise or Poisson noise** is a type of electronic noise which can be modeled by a Poisson process.

In electronics shot noise originates from the discrete nature of electric charge. The magnitude of Poisson noise varies across the image, as it depends on the image intensity. This makes removing such noise very difficult.

- **Speckle noise** the specific noises from random texture objects (like roughness of object) .

  Also it could be Film grain or granularity noises form roughness of film

Example: Image Enhancement (Quality Improving).

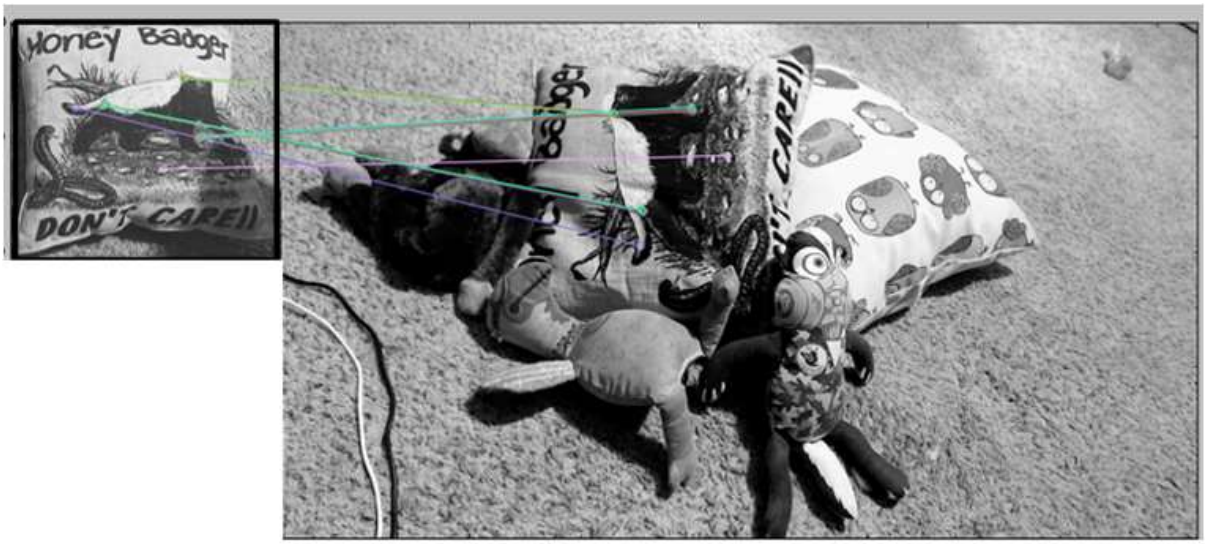
Original

Contrast Stretched

Histogram Equalization

Example: Image Enhancement (Quality Improving) using simple transformations.

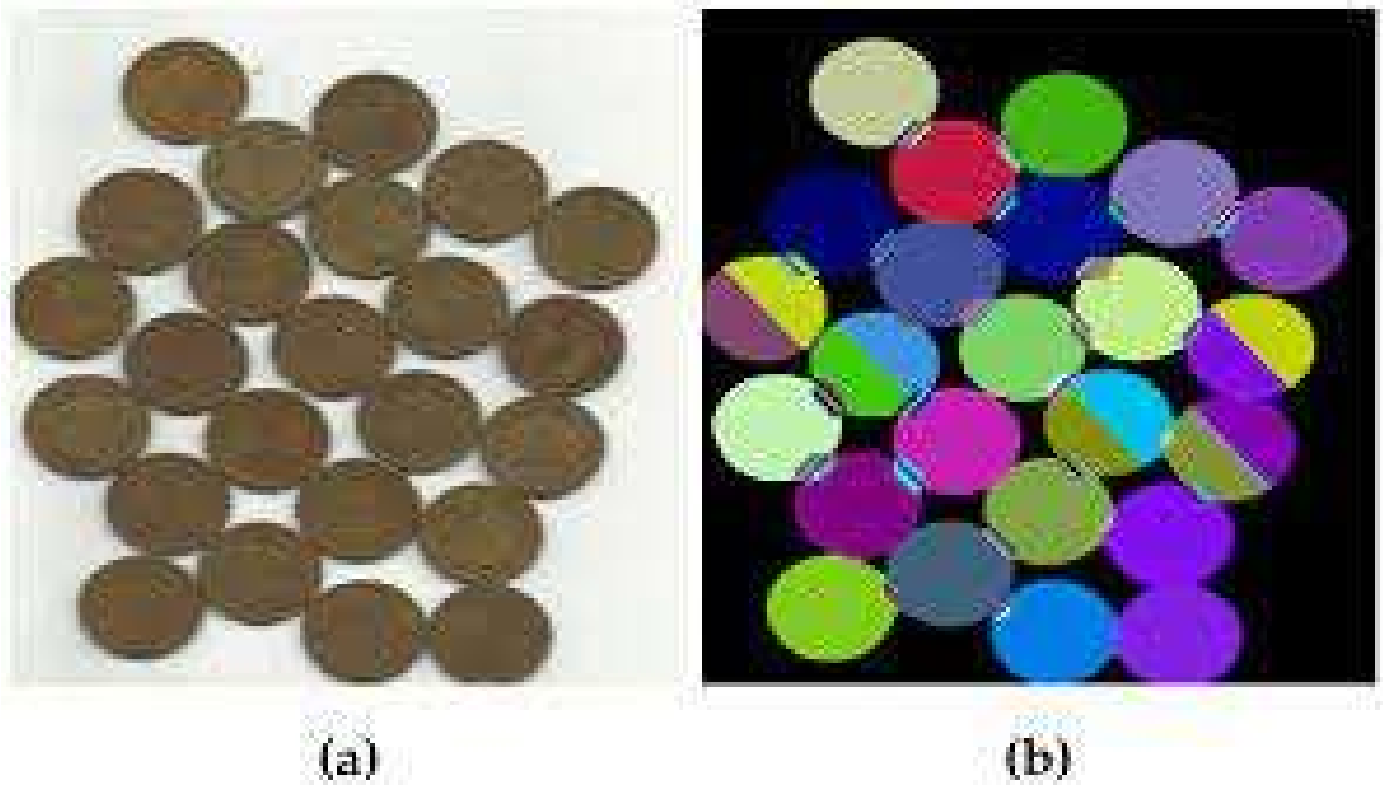
Example: Object searching using correlation.



Example: color filtering.

Example: Color coarse segmentation

Example: Watershed based instance segmentation



Example: Moving objects selection using optical flow on video (simplest by subtraction of frames)

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