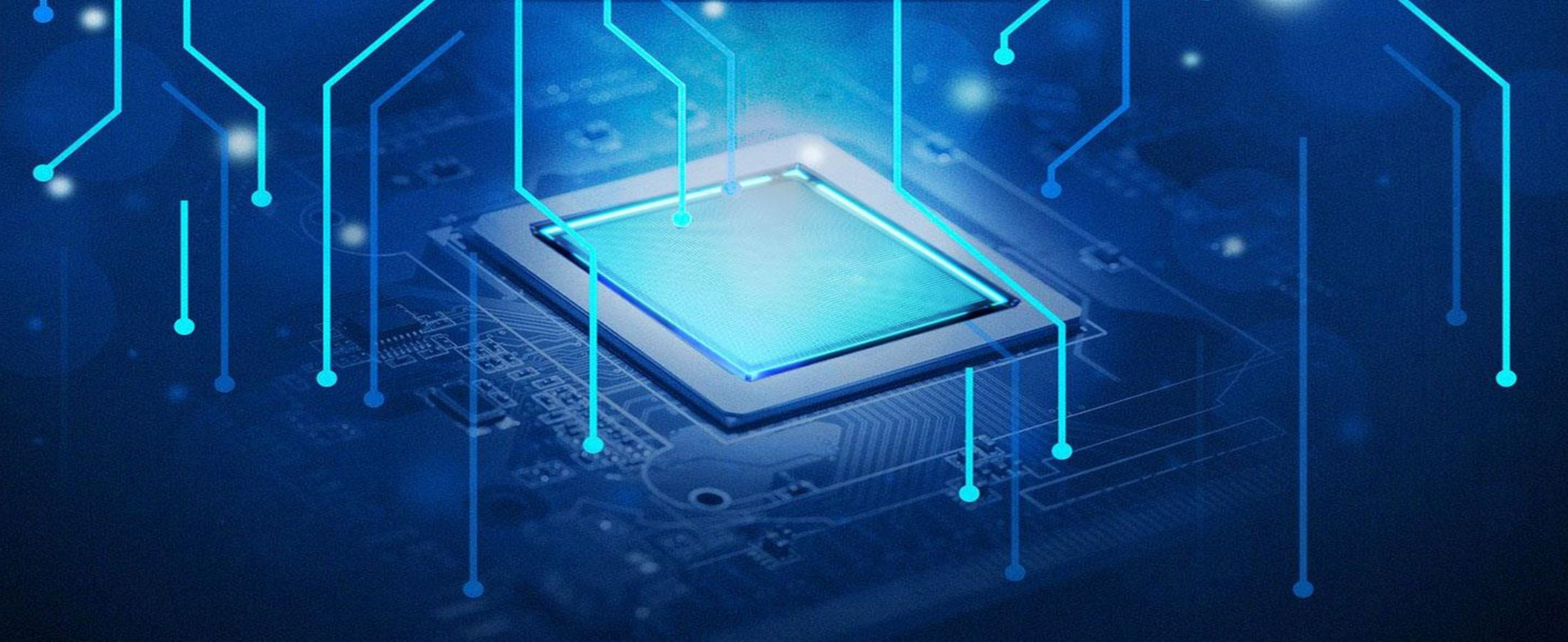


AI for EDGE

Data preparation and preprocessing

Outline

- Machine vision workflow
- Image acquisition
  - Digital image representation
- Pre-processing
  - Re-sampling
  - Noise reduction
  - Contrast enhancement
  - Normalization

Machine vision workflow

The workflow of a typical AI based Machine Vision system includes four steps

1. The image acquisition is done through a Plug n Play camera setup that optimizes the acquisition process.
2. Data preparation is done by configuring and collecting training images.
3. Specialized deep learning architecture trains are used to optimize models using cloud infrastructure.
4. The optimized model is deployed for inferencing in an edge device and monitored for accuracy.

The first step of the workflow, image acquisition is a complex process and has a lot of challenges.

- A natural image captured with a camera, telescope, microscope, or other type of optical instrument displays a continuously varying array of shades and color tones
- The accuracy required for digital conversion of analog video signals is dependent upon the difference between a digital gray-level step and the root-mean-square noise in the camera output.
- CCD cameras with an internal analog-to-digital converter produce a digital data stream that does not require resampling and digitization in the computer.
- Images captured with CCD or CMOS image sensors can be rendered in color, provided the sensor is equipped with miniature red, green, and blue absorption filters fitted over each of the photodiodes in a specific pattern.

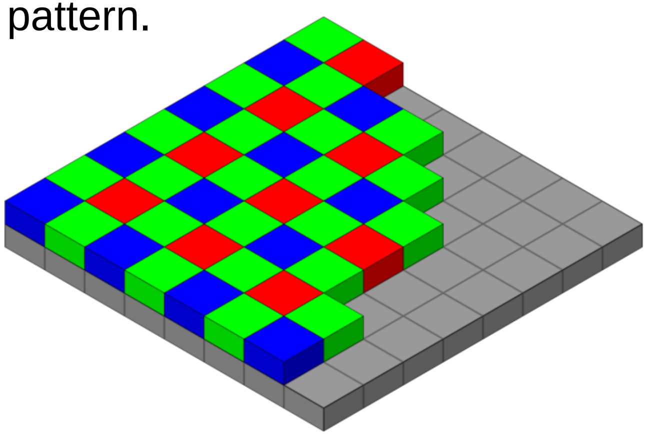


Image source: Wikipedia

Grayscale

- These black, white, and gray brightness levels are all combined in what constitutes the grayscale or brightness range of the image.
- A higher number of gray levels corresponds to greater bit depth and the ability to accurately represent a greater signal dynamic range
- At the lower resolutions (below 5-bit), the image begins to acquire a mechanical appearance having significantly less detail, with many of the specimen regions undergoing a phenomenon known as gray-level contouring or posterization.
- Gray-level contouring becomes apparent in the background regions first

Bit Depth	Grayscale Levels	Dynamic Range (Decibels)
1	2	6 dB
2	4	12 dB
3	8	18 dB
4	16	24 dB
5	32	30 dB
6	64	36 dB
7	128	42 dB
8	256	48 dB
9	512	54 dB
10	1,024	60 dB
11	2,048	66 dB
12	4,096	72 dB
13	8,192	78 dB
14	16,384	84 dB
16	65,536	96 dB
18	262,144	108 dB
20	1,048,576	120 dB

Image source: Xerox

Color space models

- All processing operations that are performed on grayscale images can be extended to color images by applying the algorithms to each color channel separately, then combining the channels
- 8-bit components are combined to produce 24-bit pixels (referred to as true color), although some applications may require a greater or lesser degree of color resolution
- Primary colors constitute a color space (commonly referred to as a color gamut)
    - RGB (red, green, blue)
    - CMY (cyan, magenta, yellow)
    - HSI (hue, saturation, intensity)
    - HSL (hue, saturation, lightness)
    - HSB (hue, saturation, brightnes)
- Grayscale digital images can be rendered in pseudocolor by assigning specific gray level ranges to particular color values.

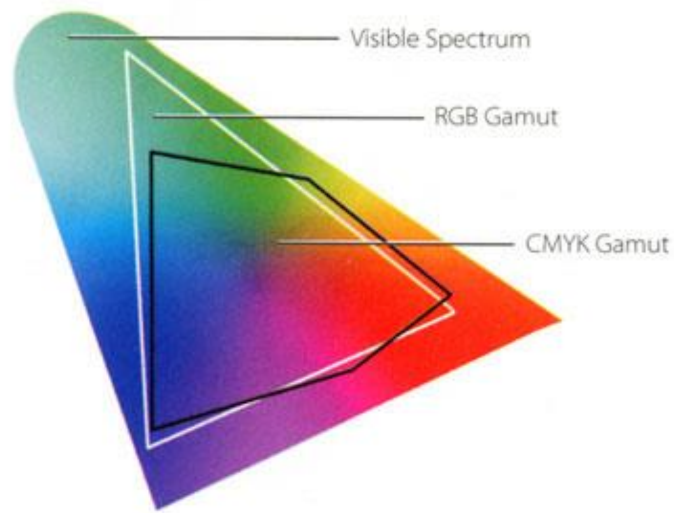


Image source: Mosaic Design Services

Image acquisition

- Usually color cameras along with white light are the first choice when objects are to be distinguished on the basis of color.
- Sometimes is need to ‘highlight’ certain wavelengths more than others to increase the contrast of the features of interest. Using color bandpass filters with monochrome cameras is an efficient and cost-effective way to accomplish this.

(a) four liquid capsules under inspection shown in color,
(b) capsules viewed with a monochrome camera yield a contrast of 8.7%,
(c) with a monochrome camera and green filter yield a contrast of 86.5%.

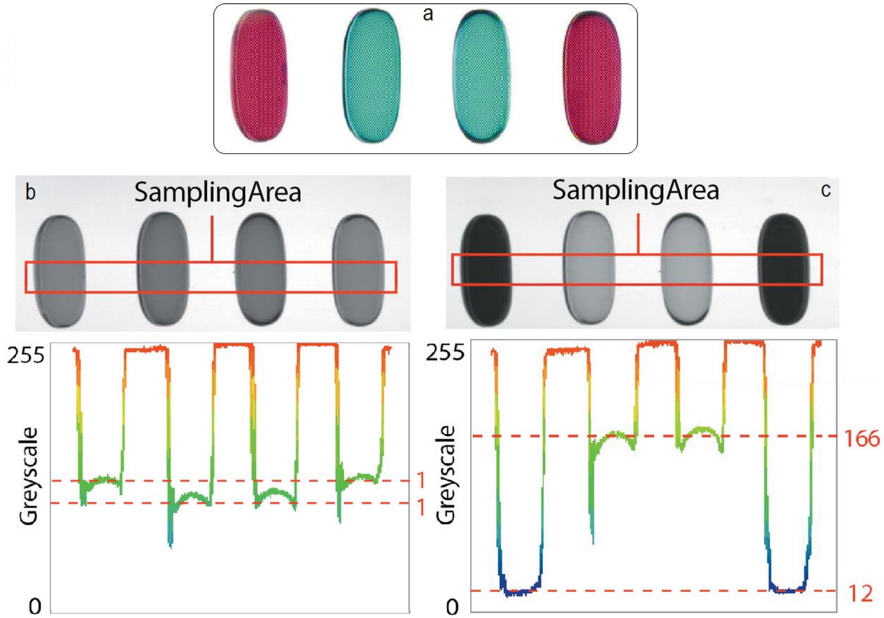


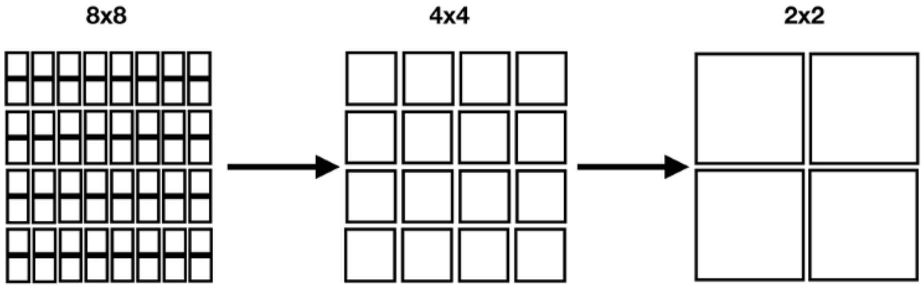
Image source: edmundoptics.com

Pre-processing

- Before a computer vision method can be applied to image data in order to extract some specific piece of information, it is usually necessary to process the data in order to assure that it satisfies certain assumptions implied by the method.
  Examples are:
  - Re-sampling to assure that the image coordinate system is correct.
  - Noise reduction to assure that sensor noise does not introduce false information.
  - Contrast enhancement to assure that relevant information can be detected.
  - Normalization to mitigate the potential negative effects of lightning inconsistencies.

- Resampling: the geometric transformation of discrete image
- Practical uses of image resampling:
  - distortion compensation of optical systems
  - registration to some standard projection
  - geometrical normalization for image analysis

- When an image is resampled, it uses interpolation by using known data to estimate values at unknown points to create pixels.



Pre-processing

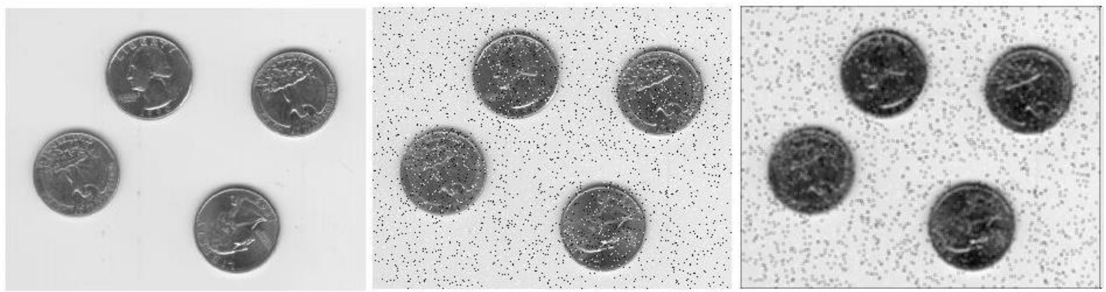
Noise is the result of errors in the image acquisition process. There are several ways that noise can be introduced into an image, for example:

- If the image is scanned from a photograph made on film, the film grain is a source of noise.
- Noise can also be the result of damage to the film, or be introduced by the scanner itself.
- If the image is acquired directly in a digital format, the mechanism for gathering the data (such as a CCD detector) can introduce noise.
- Electronic transmission of image data can introduce noise

You can use filtering to remove certain types of noise.

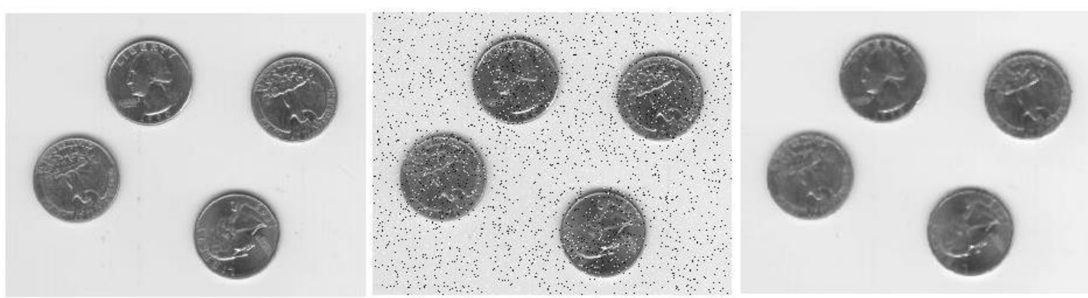
Pre-processing

- Remove noise by Linear Filtering
  - Certain filters, such as averaging or Gaussian filters, are appropriate for this purpose.



origin noise filter output

- Remove noise using a Median Filter
  - Median filtering is a specific case of order-statistic filtering, also known as rank filtering.

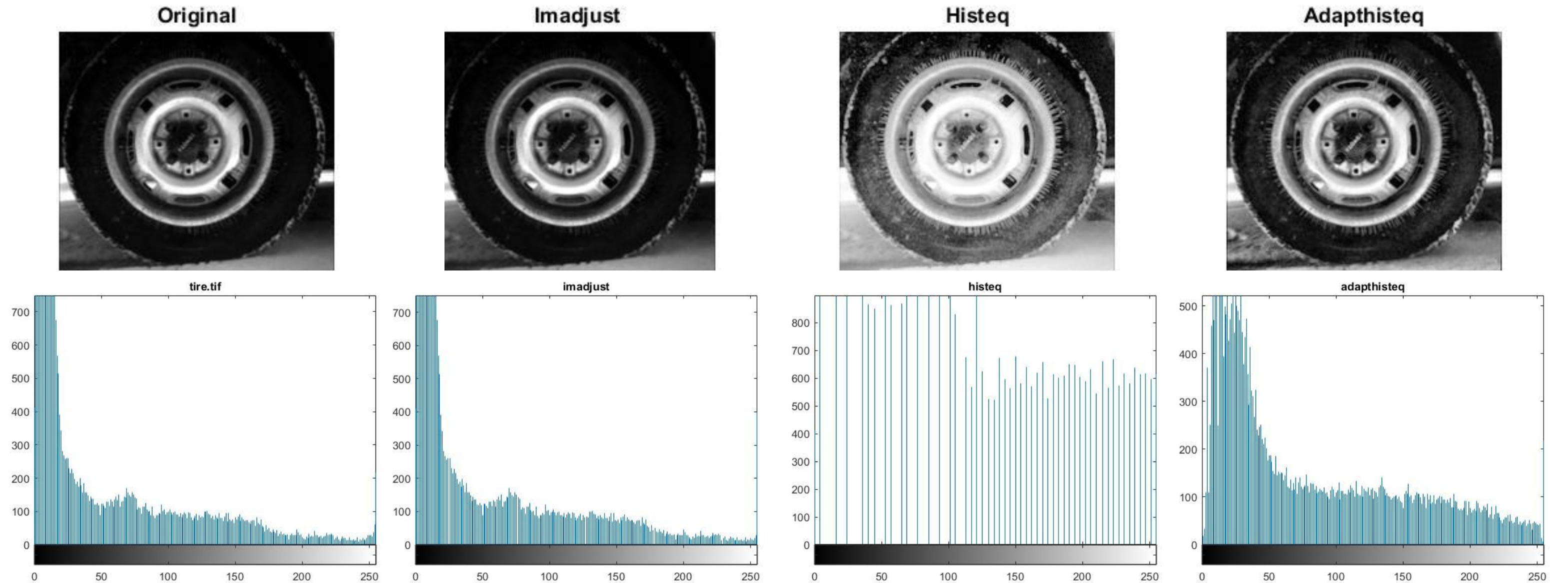


origin noise filter output

Pre-processing

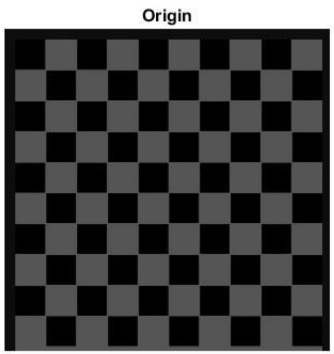
Contrast Enhancement Techniques

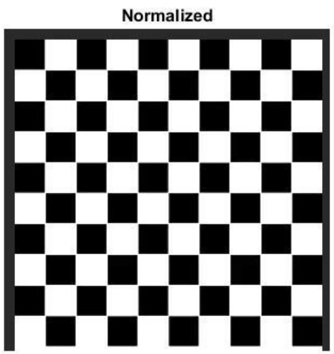
- intensity value mapping,
- histogram equalization,
- contrast-limited adaptive histogram equalization
  (it operates on small data regions (tiles) rather than the entire image. Each tile's contrast is enhanced so that the histogram of each output region approximately matches the specified histogram)



Normalization

- Essentially, in the process of normalization, the intensities in the target image are taken into account and aligned with the range of intensities in the model.
- Normalization involves calculating the pixel intensities and average brightness of the whole image and adjusting it according to desired range in the model.





- For instance, the intensity range of our target image is 50 to 180, and the range within the model is 0 to 255. The process of normalization would entail subtracting 50 from each of the pixel values, making the range 0 to 130. Then, each pixel intensity is multiplied by 255/130, making the range 0 to 255.
- The advantage here is that you have a relative output rather than an absolute output, which is of course more likely to result in accurate matching.

Data preparation

- The risk of overfitting forces us to divide the dataset into subsets. In practice three are usually used:
  - Training set - used to train the model (e.g. through a gradient descent). This is usually between 60% and 90% of all data.
  - Validation set - used to evaluate the model after each epoch training. The main purpose of this collection is to verify that the model is correct generalizes to data outside the training set. Usually it is between 10% and 20% all data.
  - Test set - used for the final evaluation of the model after completion training. It is used to avoid overfitting the model to the validation set that may result from hyperparameter tuning. Usually it is from 10% to 20% of all data.

Related topics

Gonzalez, Wintz, Digital Image Processing. Addison-Wesley 2017.

Goodfellow, I., Bengio, Y., Courville, A., Deep learning: systemy uczące się. Wydawnictwo Naukowe PWN, 2018.