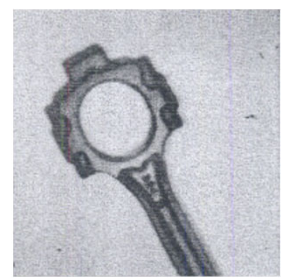
Mathematical Morphology (Week 2)

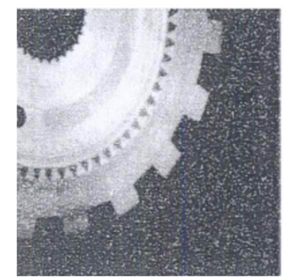
Remote Sensing

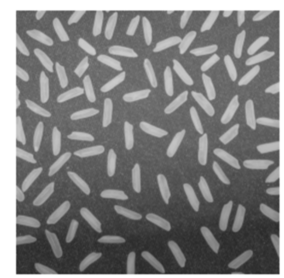
- Remote sensing is the acquisition of information about an object or phenomenon without making physical contact with the object, in contrast to on-site observation.
- Due to the advancement of drones, now remote sensing is not limited to satellite-based earth observation, it is now frequently used in various domains such as agriculture, military, humanitarian applications etc.
- One of the limitations while working with a consumer-grade drone is the amount of noise one can encounter in data.
- Due to the small size of the drone's sensor, the captured image looks noisy with non-linear illumination, especially when observing shadow regions.
- One of the possible solutions for such noisy and non-linearly illuminated data is image filters.

Image Filters

- The common image related artifacts during image acquisition are noise caused due to external interference and imbalance in illumination.
  - Salt and pepper noise contains random occurrences of both black and white intensity values.
  - Impulse noise contains only random occurrences of white intensity values.
  - Gaussian noise contains variations in intensity that are drawn from a Gaussian or normal distribution and is a very good model for many kinds of camera sensor noise.
  - Uneven illumination is one of the most unavoidable issues that make images look imperfect.

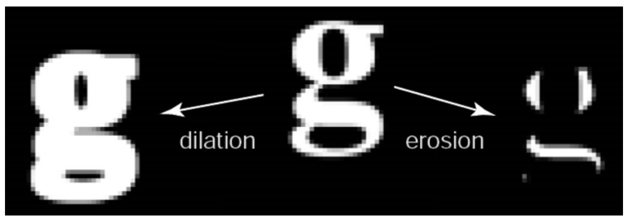






Mathematical Morphology

- Mathematical Morphology is a tool for extracting image components that are useful for representation and description.
- The shapes of objects in a binary image are represented by object membership sets. This theory can be extended to grayscale images.
- Morphological operations can simplify image data, preserve the objects' essential shape characteristics, and can eliminate irrelevant objects.
- The two basic morphological set transformations are:
  - Dilation
  - Erosion



Mathematical Morphology

- Dilation (represented by $\bigoplus$) operation usually uses a structuring element (S) for probing and expanding the shapes contained in the binary input image (I).
  - Suppose, S is centred at reference pixel (i, j) on I, which is denoted as $S_{(i,j)}$, then dilated pixel $D_{(i,j)}$ can be defined as:

$$D_{(i,j)} = I \bigoplus S_{(i,j)} = \max\left(\bigcup I \bigotimes S_{(i,j)}\right)_{(i,j)\in I}$$

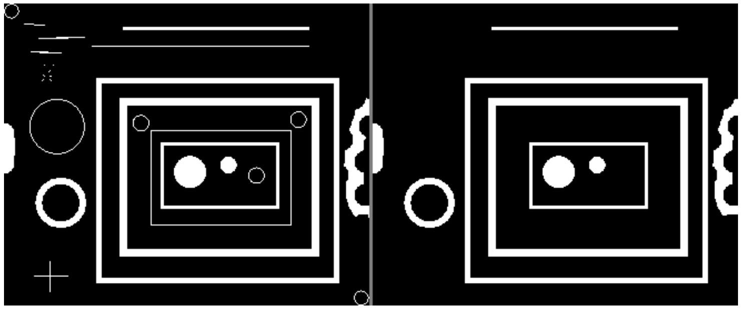
where, $\bigotimes$ represents element by element multiplication of metrices.

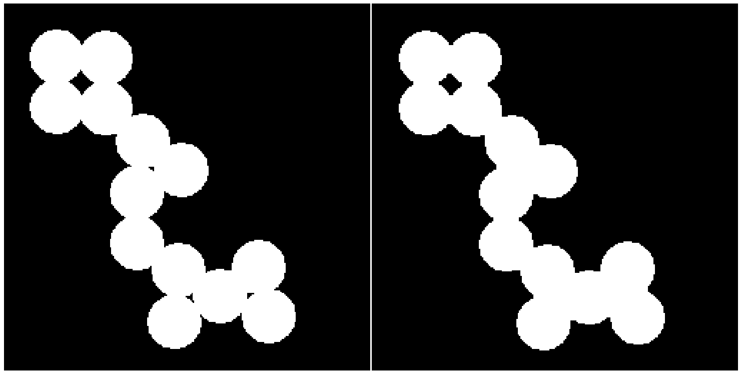
- Erosion (represented by $\ominus$) operation usually uses inverse logic.
  - Suppose, S is placed with its reference pixel at (i, j) on I, which is denoted as $S_{(i,j)}$, then eroded pixel $E_{(i,j)}$ can be defined as:

$$E_{(i,j)} = I \ominus S_{(i,j)} = \min\left(\bigcup I \bigotimes S_{(i,j)}\right)_{(i,j)\in I}$$

Mathematical Morphology

- Morphological opening (○): First erode, then dilate, using the same structuring element for both operations.
  - Morphological opening is useful for removing small objects and thin lines from an image while preserving the shape and size of larger objects in the image.
- Morphological closing (●): First dilate, then erode, using the same structuring element for both operations.
  - Morphological closing is useful for filling small holes in an image while preserving the shape and size of large holes and objects in the image.





Mathematical Morphology

- White top-hat: It transforms I using following equation:

$$T^{w}{}_{(i,j)} = I - (I \circ S_{(i,j)})$$

  where, $\circ$ denotes the opening operation.

- Black top-hat: It transforms I using following equation:

$$T^{B}{}_{(i,j)} = \left(I \bullet S_{(i,j)}\right) - I$$

  where, $\bullet$ denotes the closing operation.

- Top-hat transforms are used for various image processing tasks, such as feature extraction, background equalization, image enhancement, etc.