Chapter 4

Introduction to Image Enhancement:

- Image enhancement serves two main purposes: improving perceptibility for human observers and preparing images for automated analysis.
- Evaluation of enhancement methods requires a criterion for image quality.
- Different enhancement techniques are utilized, including contrast enhancement, edge enhancement, and noise reduction.
- In medical imaging, contrast enhancement is crucial for reducing artifacts, noise, and emphasizing differences between objects.
- Quantitative measures of image quality, such as spatial resolution and contrast, are essential for assessing enhancement success.

Measures of Image Quality:

- Spatial resolution and contrast resolution determine the smallest structure represented in a digital image and the visibility of structures, respectively.
- Perceived resolution, considering contrast, may exceed technical resolution due to factors like contrast enhancement.
- Contrast is measured using various methods, including global contrast, rms contrast, entropy, and contrast from the co-occurrence matrix.
- The modulation transfer function (MTF) describes contrast loss in an image due to factors like reconstruction or transfer processes, offering insights into image degradation and human vision discrimination performance.

Signal-to-Noise Ratio (SNR):

- Noise in images disrupts clarity and affects object perception.
- It's typically described as random intensity fluctuations with zero mean and a certain variance.
- The SNR measures the ratio of object-background contrast to noise variance, impacting object detectability.
- SNR increase suggests image enhancement, but the difference signal must reflect the object-background intensity difference.
- However, SNR doesn't consider factors like object size, shape, or texture, affecting its absolute use in determining object visibility.

Image Enhancement Techniques:

- Contrast Enhancement: Linearly adjusts intensity values to improve global contrast, crucial for mapping images onto limited intensity ranges.
- Histogram Equalization: Maximizes entropy by redistributing intensity values, enhancing contrast. However, it may lead to information loss or undesired effects.
- Adaptive Histogram Equalization (AHE): Locally adapts histogram equalization, improving contrast in specific image regions while limiting noise amplification.
- Edge-Enhancement: Techniques like Sobel filters or Laplacian of Gaussian (LoG) filters highlight edges, aiding in edge detection and image enhancement.

Resolution Enhancement:

- Interpolation: Utilized for zooming, shrinking, rotating, and geometric corrections in digital images by estimating values at unknown locations using known data.
- Shape-Based Interpolation: Infers a shape gradient between slices, transferring features from low to high-resolution realms.

- Sobel Filter: Calculates image intensity gradients to detect edges, useful in identifying abrupt intensity changes indicative of edges.
- Laplacian of Gaussian (LoG) Filter: Highlights regions of rapid intensity change by convolving the image with the Laplacian of a Gaussian kernel, aiding in edge detection and enhancement.

Types of Noise:
- Gaussian Noise: Follows a Gaussian distribution, typically caused by sensor or electronic interference.
- Salt and Pepper Noise: Occurs as white and black pixels due to errors in image acquisition or transmission.
- Speckle Noise: Found in ultrasound or laser images, arising from sound or light wave interference.

Noise Reduction:
- Noise is often stationary, additive, and has zero mean.
- Noisy image g = noise-free image f + noise (n).
- Linear filtering, median filtering, diffusion filtering, and Bayesian restoration are common noise reduction schemes.

Linear Filters:
- Linear filtering assumes local constancy in the image and averages over a neighborhood.
- Other filters include median, diffusion, and Bayesian, each with specific assumptions about the image.

Noise Reduction in Medical Images:
- Challenging due to the need to maintain spatial resolution.
- Linear filtering may fail in low SNR or high noise ratio cases, requiring edge-preserving smoothing methods.

Order-Statistic Filters:
- Utilize pixel value ranking in a neighborhood, with the median filter being the most common.
- Offers excellent noise reduction with less blurring compared to linear smoothing.

Max and Min Filters:
- Based on the 100th and 0th percentiles respectively, providing maximum and minimum value filtering.

Diffusion Filtering:
- Models noise reduction akin to diffusion of material, accommodating various edge models.
- Inhibits diffusion across edges for enhancement, treating boundaries differently.

Gradient Adaptive Smoothing:
- An iterative process similar to diffusion filtering, aiming for edge-preserving smoothing.

Bilateral Filtering:
- Single-step procedure approximating anisotropic diffusion and adaptive smoothing iteratively.