FILTERING TECHNIQUES

Filtering techniques in medical imaging are mathematical operations applied to digital medical images (such as X-ray, CT, MRI, or Ultrasound) to suppress noise, enhance image contrast, preserve or sharpen edges, and extract clinically relevant information, thereby improving the accuracy of image interpretation and computer-aided diagnosis.

NOISE REMOVAL TECHNIQUES

Noise removal is an important step in medical image processing because it improves image quality and helps doctors clearly observe anatomical structures. MRI images are commonly affected by different types of noise, such as **Salt-and-Pepper noise, Gaussian noise, Speckle noise, and Poisson noise**. To remove these noises, several filtering techniques are used, including the **Median Filter, Gaussian Filter, and Wiener Filter**. Each filter is effective for different types of noise. The **Median Filter** is best for removing Salt-and-Pepper noise, the **Wiener Filter** is effective for Gaussian and Speckle noise, and the **Gaussian Filter** is mainly used for smoothing images and reducing blur. Using the appropriate filter improves image quality and supports accurate medical diagnosis.

- Weiner Filter
- Median Filter
- Gaussian Filter
- Speckle noise
- Gaussian noise

- Salt and Pepper noise
- blurred noise
- Poisson noise

Median Filter

The Median filter is the popular known order-statistic filter in digital image processing. Median filter is very popular technique for the removal of impulse noise because of its good de-noising power and mathematical accuracy. The value of a pixel is replaced by a median of the intensity levels in the neighborhood of that pixel by the Median Filter. A fixed filtering window size is used for outcome of neighborhood pixels by the Median Filter. The median filters are implemented consistently across the image and therefore tends to modify both noisy and noise free pixels present in the image. Relation to this, there is always a chance of replacement of good pixels by some corrupted ones. Therefore, de-noising is often accomplished at the expense of blurred and distorted features thus removing fine details present in the image.

Weiner Filter (WF)

The goal of the Weiner filter is to remove the noise or filter out the noise that has corrupted a signal. This filtering technique is based on a statistical approach to filter the noise. Typical filters are designed for a wanted frequency response and Weiner filter is the good example for this kind of approach. This filtering technique approaches filtering from a different angle. Before starting with this technique one should have the knowledge of the spectral properties of the original signal and the noise present in the image, one seeks the LTI filter (Linearity and Time-Invariance) whose outcome will be closer to the original signal present in the image as achievable. Wiener filter is a technique which performs optimal trading between inverse filtering and noise smoothing. It removes the blurring and additive noise present in the image and it is also very optimal in relation to the mean squared error where it minimizes the overall Mean Square Error in the operation of the filtering technique for noise removal.

Wiener filters are usually defined and characterized by the following

a) Hypothesis: signal and additive noise are inactive linear random processes with known spectral characteristics.
b) Necessity: The filter must be physically reachable and can be accessed.
c) Performance criteria: It depends on minimum Mean Square Error.

Gaussian filter

Speckle Noise is typical noises which is caused due to internal or external factor and are generally present in the digital images and MRI images. Gaussian filter is implemented to remove the Speckle Noise present in ultra sound images or MRI brain images. In this technique, the average value of the surrounding pixel or neighboring pixels replaces the noisy pixel present in the image which is based on Gaussian distribution.

Gaussian and Speckle Noise. Gaussian filter give best results for Gaussian Noise images. Comparative results of all filters used for the noise are shown among all filtering methods based on image size, clarity and histogram. The results, which we have achieved, are more useful and they prove to be helpful for general to analyze which noised image can be de-noised using best filtering algorithm.

Salt Pepper Noise

The image which is low in quality has bright and dark pixels present in it which causes noise in it also referred as Salt Pepper noise. An image which contains Salt Pepper noise will generally have bright pixels in dark portion and dark pixels in bright portion of the image. Black and white dots appear in the image as a result of this noise shown in the fig 10(a). Due to sharp and unexpected changes of image signal the noise arises. Dead pixels, analog-to-digital converter errors, bit errors in transmission, etc. are caused due to the presence of Salt Pepper noise in the image. This kind of noise can be removed by using Dark Frame Subtraction (DFS) and by constructing new data points around dark and bright pixels which is obtained by the Median filter or morphological filter.

Speckle Noise

The Speckle Noise is defined as a noise which is present in the images and which degrades the quality of an image. Speckle Noise is a phenomenon that convoys all coherent imaging modal quality in which images are produced by interfering echoes of a transmitted waveform that originate from diversity of the studied objects [5].These are the granular noises that are fundamentally present in the image and reduce the quality of the active radar and Synthetic Aperture Radar (SAR) images or Magnetic Resonance [6]. Imaging (MRI) images is referred to as Speckle Noise. If Speckle Noise is present in the conventional radar results from random variations in the return signal from an object which is no longer image process signal increases the mean grey level in an image. A Speckle Noise is the coherent imaging of objects in the image. In fact, it is caused due to errors in data transmission. This kind of noise affects the ultrasound images and MRI images.

Speckle Noise follows a gamma distribution and is given as:

$$(g) = [\propto -1 \ (\propto -1)! \propto e-]$$

Where, $\propto$ is the shape parameter of gamma distribution, ‘a’ is the variance and ‘g’ is the gray level.

Poisson Noise

Poisson Noise is a electronic noise that occurs in an image when the limited number of particles that carry energy, such as electrons in an electronic circuit or photons in photosensitive device, is small enough to give rise to detectable statistical variations in a measurement. Consider light a stream of discrete photons coming out of a source and hitting a point which creates a visible spot, the physical process which governs the light emission are such that those photos which are emitted from the light source hits the point many times but to create visible spot billions of photons are needed. However, if the source is not able to emit handful number of photons which hits the point every second then this noise is caused.

The formula of adding the Gaussian Noise to an image is:

J = imnoise (I,’poisson’) where I is double precision, then input pixel values are interpreted as means of Poisson distributions.

Blurred Noise

Blurred Noise is caused due to the light intensity and external factors. Capturing reasonable photos under low light conditions using a hand-held camera can be annoying experience. Often the photos taken are blurred or noisy. These kind of images containing hazy and blurred pixels are referred to as Blurred Noise which is present in the image.

SMOOTHING TECHNIQUES

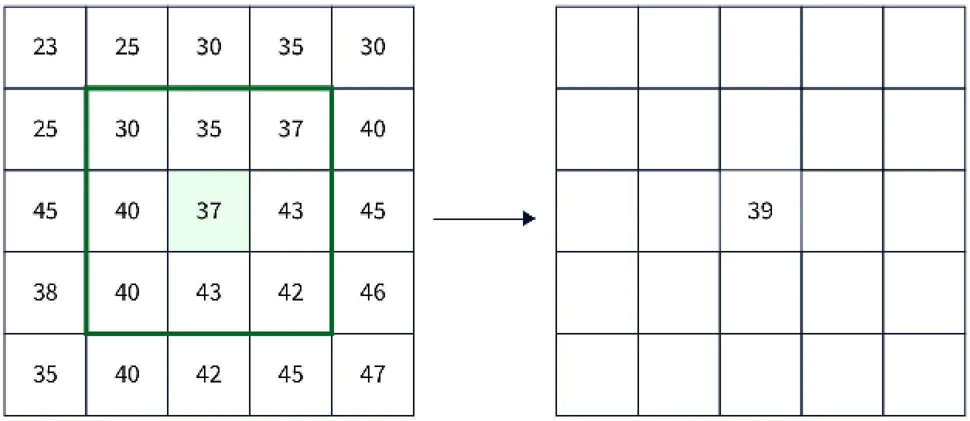
Smoothing in image processing refers to the process of reducing noise or other unwanted artifacts in an image while preserving important features and structures. The goal of smoothing is to create a visually appealing image that is easy to interpret and analyze. Smoothing techniques use various algorithms, such as filters or convolutions, to remove noise or other distortions in the image. Effective smoothing requires striking a balance between removing unwanted artifacts and preserving important image details, and is an essential step in many image processing applications, including image segmentation, object recognition, and computer vision.

Types of Smoothing Filters

Smoothing filters, also known as blurring filters, are a type of image filter that are commonly used in image processing to reduce noise and remove small details from an image. There are several types of smoothing filters, including mean filter, median filter, Gaussian filter, and bilateral filter.

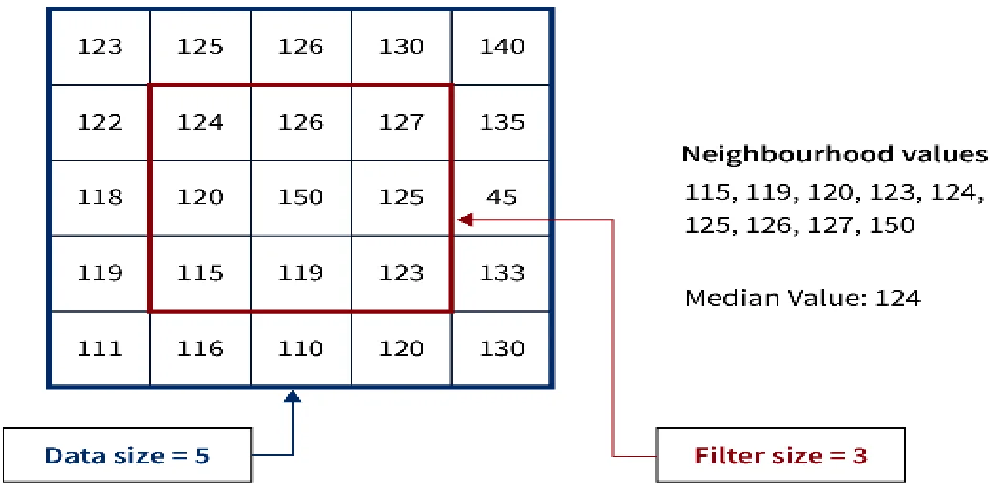
Mean Filter

The mean filter is a type of **linear smoothing filter** that replaces each pixel in the image with the average of its neighboring pixels. The size of the neighboring pixels is defined by the filter kernel or mask. The larger the kernel, the stronger the smoothing effect. Mean filters are easy to implement and are commonly used in low-level image processing tasks such as noise reduction and edge detection. However, they tend to blur edges and details in the image, leading to loss of image quality.



Median Filter

The median filter is a type of **nonlinear smoothing filter** that replaces each pixel in the image with the median value of its neighboring pixels. The size of the neighborhood is also defined by the filter kernel. Unlike the mean filter, the median filter does not blur edges and details in the image. Instead, it preserves them while removing the noise. Median filters are commonly used in image processing tasks that involve removing salt and pepper noise from the image.



Gaussian Filter

The Gaussian filter is a type of **linear smoothing filter** that is based on the Gaussian distribution. The filter works by convolving the image with a Gaussian kernel.
The **Gaussian kernel** has a bell-shaped curve that determines the weight of each pixel in the neighborhood. Pixels closer to the center of the kernel have a higher weight than pixels farther away. The Gaussian filter is a good choice for smoothing images while preserving edges and details. However, it is computationally expensive and can produce ringing artifacts around edges.

$$K = \frac{1}{256}\begin{bmatrix} 1 & 4 & 6 & 4 & 1 \\ 4 & 16 & 24 & 16 & 4 \\ 6 & 24 & 36 & 24 & 6 \\ 4 & 16 & 24 & 16 & 4 \\ 1 & 4 & 6 & 4 & 1 \end{bmatrix} = \frac{1}{16}\begin{bmatrix} 1 & 4 & 6 & 4 & 1 \end{bmatrix} * \frac{1}{16}\begin{bmatrix} 1 \\ 4 \\ 6 \\ 4 \\ 1 \end{bmatrix}$$

Bilateral Filter

The bilateral filter is a type of **nonlinear smoothing filter** that uses a combination of spatial and range filtering. The spatial filter is similar to the Gaussian filter, while the range filter is based on the difference in pixel intensities. The bilateral filter preserves edges and details while removing noise. It is commonly used in image processing tasks such as image denoising, edge-preserving smoothing, and tone mapping.

$$BF[I]_p = \frac{1}{W_p} \sum_{q \epsilon S} G_{\sigma_s}(||p-q||) G_{\sigma_r}(|I_p - I_q|) I_q$$