Chapter 3

PREPROCESSING

3.1 General Background

Medical Image processing is an emerging area in the research for various disease detection and diagnosis which aids the medical practitioner for easy diagnosis of diseases accurately. Acquisition of medical image is a challenging task in which this process is accomplished based on the devices and present situation of the patients. Due to various defects in the image acquisition, the images may be affected with various noises which are discussed in the forthcoming sections of this chapter. In order to overcome the issues, it is necessary for a method to eliminate the external entities such as noises; which affects the image during the acquisition. Hence, it is necessary to preprocess the images for noise elimination. Preprocessing is a process which is used to boost the precision and interpretability of an image. Image preprocessing is a noteworthy and challenging task in the CAD system. In medical image processing, preprocessing of an image is very important so that the extracted image does not have any impurities, and it is accomplished to be better for the forthcoming process such as segmentation, feature extraction, etc. Only the correct segmentation of the tumor will yield the accurate result. Accurate detection leads to precise feature extraction and in turn gives perfect classification. The accurate tumor segmentation is promising, only if the image is preprocessed clearly.

3.2 Introduction

The main goal of preprocessing is to enrich the visual look of the images. Preprocessing mainly aims to remove the clamor, stabilizing the intensity of the images and clear the artifacts. Image preprocessing is the technique of enhancing the image data prior to computational processing. In general, image preprocessing can be carried out in any one of the following forms:

- *Image resampling:* Altering the pixel dimensions of the image is called 'resampling.' Image resampling is a procedure to transform a sampled image from one coordinate to another. Using the mapping function of the dimensional transformation, the two coordinate systems are correlated to each other. The reverse mapping function is applied to the output pixel, so that the obtained 'resampling pixel' is reversed to obtain the original input pixel. In some cases, the resampling pixel does not match with the input pixel. In order to overcome this, a matching domain must be created for the input pixel and the range of the mapping function. This can be accomplished by digitizing the image into continuous surface by means of 'image reconstruction'. After the reconstruction of input, it is ready to be resampled at any position.

  From the fig. 3.1., the input image samples are resampled by means of image reconstruction technique in order to attain a pleasant output samples. For example, if the image is zoomed then each pixel is represented as a square shaped pixels in the zoomed image. In order to avoid this, the image reconstruction techniques are used to regain its original shape.

- *Contrast Enhancement:* To make the image more suitable for definite applications, contrast enhancement must be used. It improves the visibility and the

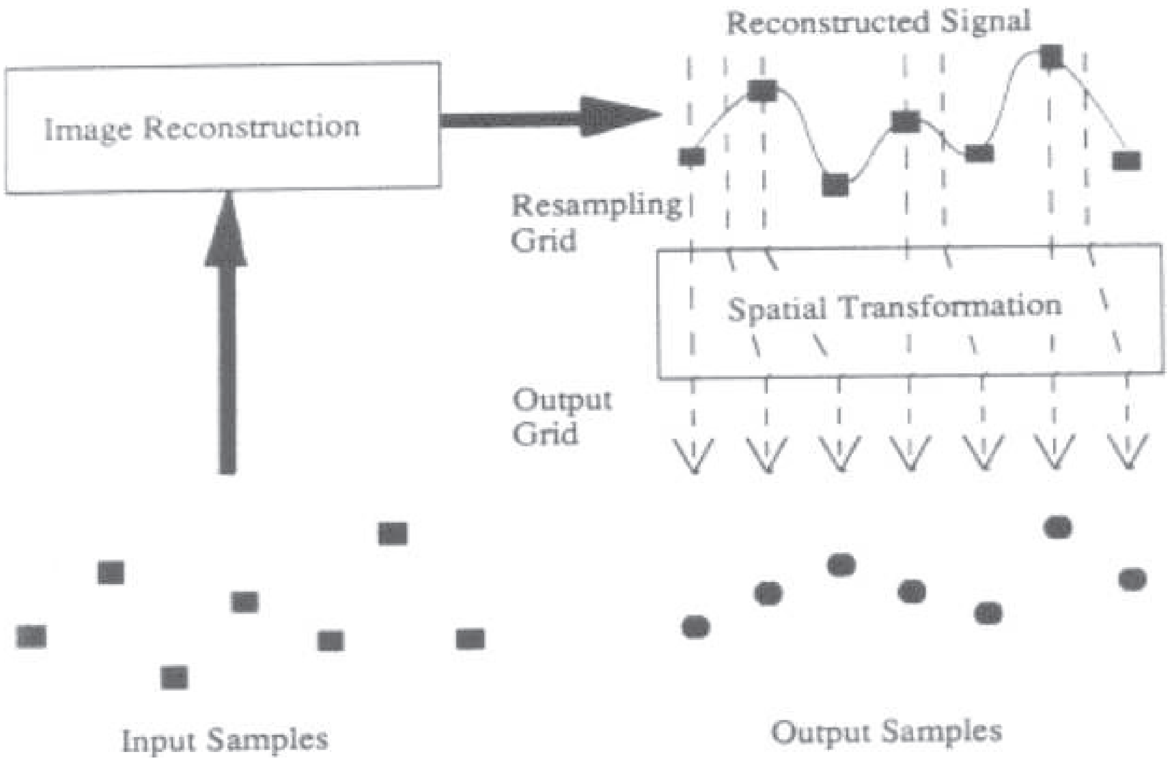


Fig. 3.1: Image Resampling

transparency of the image and the original image is more acceptable to process the computer. As the image values of the low contrast images are extreme, the contrast enhancement stretches the intensity of the pixel. Commonly, the image can have poor statistical range or misrepresentation of pixels either due to low quality of the imaging devices or the extreme external conditions during acquisition process. Among the various contrast enhancement techniques, histogram modification procedure is extensively used because of its easiness and effectiveness. The process of histogram equalization is to stretch the intensity of the input image to create an identical distribution so that the active range of the image is fully demoralized.

Local Dissimilarity Stretching (LDS) is a boosting method to locally adjust the intensity value of an image both in darkest and brightest part of the image simultaneously. The LDS is implemented using sliding window concept and the midpoint is determined from the following expression:

$$MP_x(i,j) = 255 * \frac{[MP_0(i,j) - MP_{min}]}{[MP_{max} - MP_{min}]} \tag{3.1}$$

where

$MP_x(i,j)$ represents midpoint value of pixel x

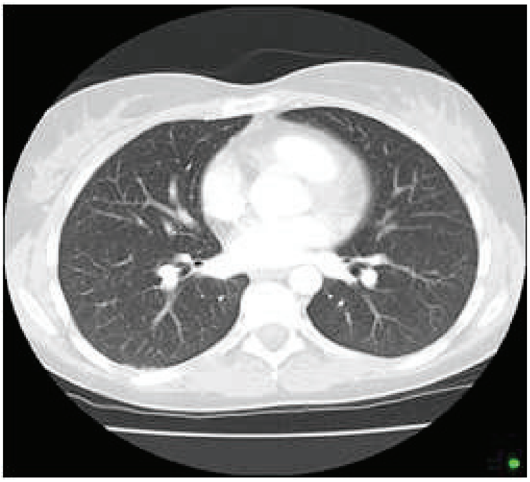
$MP_o(i,j)$ represents midpoint value of origin

MP_{min} represents minimum value of all pixels

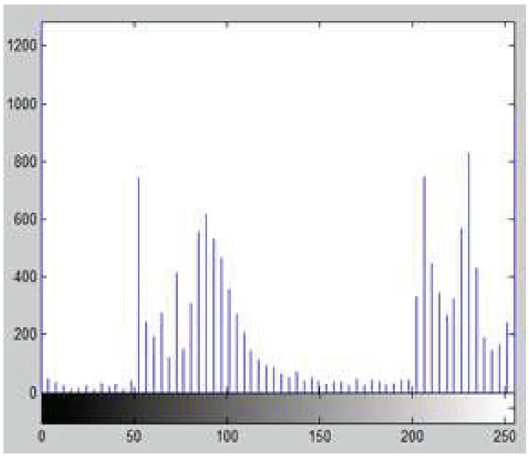
MP_{max} represents maximum value of all pixels

Fig. 3.2 depicts the normal lung image, its histogram image, contrast enhancement and its histogram image. Once the contrast enhancement is applied to the image, all the pixels in the image are more or less same and it is demonstrated by means of the corresponding histogram image.

- *Noise Removal:* At the time of image acquisition or during transmission, noises are produced. Several factors are liable for the formation of noise while acquisition or transmission. Subject to the type of noise the image can affect, it degrades the image quantification to different range. In general, the noises in the image can be classified as i) impulse noise (salt & pepper noise) - alternative black and white marks appear on the image hence it name as salt & pepper. This may be due to the sharp and abrupt deviations in image signal. ii) Gaussian noise (Amplifier noise) - each noisy pixel in the image is the summation of the correct pixel value and arbitrary Gaussian distributed value. The clamor produced due to this type, is

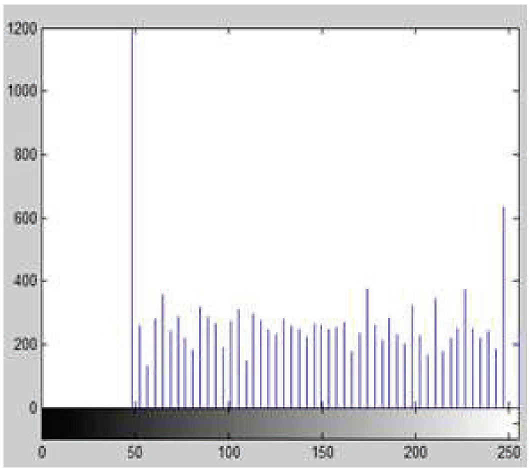


(a) Normal Lung



(b) Histogram of normal lung

(c) Contrast Enhancement



(d) Histogram of Contrast enhancement lung

Fig. 3.2: Histogram of Normal and its Contrast Enhanced Lung

independent of the pixel intensity. iii) Speckle noise (Multiplicative noise) - this type of noise was formed by multiplying some random value of uniform noise with the normal pixel. This noise weakens the quality of active RADAR. In conservative RADAR system, this type of noise is detected, only when the resumed signal from the object having less than or equal to a distinct processing unit. iv) Poisson noise or photon noise is sensed only when the number of photons detected by the sensor are not satisfactory to deliver statistical information.

Fig. 3.3: a) Original image, b) Impulse noise with 30%, c) Gaussian noise with zero mean, d) Poisson noise, and e) Speckle noise

In fig. 3.3, the original image gets corrupted by different types of noises. In the above figures (b-e) depict the noises and their names.

- *Mathematical operations:* By considering the image arithmetic operations, application of one of the standard mathematical or logical operations to two or more images is the option. The operators are applied in a step-by-step manner. That is, the value of the output pixel depends only on the value of the input pixel. Therefore, the size of the image must be the same. The major advantage of using mathematical operations is that, it is very fast and simple to implement. Alike mathematical operations, logical operations are frequently used to combine two or more binary images. In the circumstance of digital images, the logical operator is usually applied in a bit-wise manner.

- *Manual corrections:* The image may be well tuned by cutting out the unwanted thing in it. Editing can be done by using:

  * *Pixel-by-pixel method* - every pixel can be modified based on some criteria.

* *Using lines or splines* - by marking a line or spline in the input image editing can be processed.
* *Using predefined 2D or 3D shapes* - designing a predefined shape such as rectangle, brick or sphere by means of manual drawing make the editing more easily.

3.3 Methodology

Image feature is determined by dissimilarity, resolution and signal-to-noise ratio. Adaptive Neighborhood Contrast Enhancement (ANCE) [43] method, computes the confined dissimilarity around each pixel using a variable neighborhood. This technique takes the advantage of improving or maintaining the dissimilarity of the image, whereas suppressing the noise. The major drawback for using the ANCE method is to identify the suitable parameter for processing. In some cases, the CT images are initially preprocessed in order to remove noise as in [44]. After preprocessing, the images are segmented using Sobel edge detection method. Segmentation acts as the preprocessing stage in [45]. Now, for time reduction, instead of searching the whole slice for abnormality, the search is limited to those areas containing nodules. The images obtained from the CT or MRI devices, generally, need preprocessing before further process. Contrast enhancement, noise reduction and segmentation acts as the preprocessing step in [46]. At this juncture, for contrast enhancement, histogram equalization is used and for noise removal, average filter and different types of median filters were used. Before visualization, data are divided into multiple segments. In [80], preprocessing has two phases. At the first phase, the noises and other film artifacts can be detached by means of median filter; and in the second term, erosion is applied three times consecutively to the constructing element (CE); by decreasing the size of the CE by one for each time. The major advantage of using this type of preprocessing is to avoid over-segmentation; while keeping the structure of the tumor as it is. A review of the existing popular algorithms for both preprocessing and segmentation for color images are depicted [81]. The review suggests that the performance of these methods may vary depend upon the factors such as distribution of data, operating environment and operating parameters.

3.4 Proposed Methodology

In this study, preprocessing can be done by means of two phases. In the first phase, the appropriate slice for further study was taken into consideration based on the Artificial Bee Colony (ABC) algorithm. Once the appropriate slice is taken, then it undergoes preprocessing in order to remove noise and other artifacts by means of different linear and non-linear filters.

3.4.1 Preprocessing based on ABC

In this study, before preprocessing, Artificial Bee Colony (ABC) algorithm [82, 83] is put forth to reduce the number of slices taken into account. ABC is an optimization technique in which the foraging behavior of the honey bee is mended for choosing the nectar from the food source. This can be inter-related with the problem of choosing a specific slice from multi slice computed tomography (MSCT). Naturally, the honey bees search for the food source in a multidimensional hunt; based on their experience some honey bees such as employee and onlooker bees collect their food source. Some others (scout bee) will collect their food arbitrarily, without having any knowledge about the food source. If the collected food is more quantity than the previous attempt, then all the bees will memorize the new location where they got the food and erase the previous one. Instead of searching for the location of food, here in ABC, the slice having higher intensity values are searched by the artificial bee. As a result, the ABC algorithm pools limited search conceded by onlooker and employee bee, and overall search by scout bee. The algorithm works with the following stages:

1. Read each slice and stored it in a 2D matrix.
2. Initialize the number of slices as T(N), number of employee bee as EB(N), updation factor as σ, Onlooker bee as OB and Scout bee as SB.
3. Assign each slice to the employee bee of ABC algorithm as:
   T(N) = EB(N)
4. Compute the average intensity value of each slice:

$$AverageIntensityvalue(a_i) = \sum_{x=1}^{n} \left[\frac{n_x}{n} \right] \tag{3.2}$$

   where
   a_i is average intensity value of i
   n_x is intensity valus of the pixel x
   n is total number of intensity value

5. Choose the maximum intensity value from the overall a_i and it is assigned to the onlooker bees as:

$$OB = max \left\{ \sum_{i=1}^{n} a_i \right\} \tag{3.3}$$

6. Then and there, the employee bees become a scout bee and goes for random search. In order to choose a candidate slice from MSCT, ABC uses the following

expression as scout bee:

$$SB = IV_{ij} + \sigma(IV_{ij} - IV_{kj}) \tag{3.4}$$

where

IV_{ij} represents the intensity value of pixel i,j IV_{kj} represents the intensity value of pixel k,j σ represents the updation factor

At this point, k and j are randomly chosen indexes. That indices are compared to the specific indices (i,j). If the result is a negative one (that is, the second value has greater intensity) then, update it with -1 or update it with +1. Here, updating factor is an important switching parameter to choose a particular slice. In the ABC algorithm, the onlooker and employee bees bring out the manipulation process in the local search space while the scout bee switch the assessment process.

3.4.2 Preprocessing using various filters

Once the specific slice is chosen for preprocessing, the noises and other film artifacts can be removed by means of various filters such as adaptive median, alpha-trimmed mean, Gaussian, Gabor, high-pass, Laplacian and Bilateral filter. The working principles of these filters are discussed as such:

- *Adaptive Median filter:* The major difficulty faced by the median filter is, it cannot differentiate corrupted pixels and the normal one. This demerit could be overcome by means of Adaptive Median Filter [84]. A pixel is considered to be a 'noisy pixel', when it differs widely in terms of its structure and its properties from its surrounding pixels. The noisy pixels are then interchanged by the median values obtained from the neighborhood, which have surpassed the noise classification test.

The Adaptive Median filter works as follows:

Phase 1: $P_{11} = G_{med} - G_{min}$

$P_{12} = G_{med} - G_{max}$

if $P_{11} > 0$ AND $P_{12} < 0$, goto Phase 2

else rise the frame size

if frame size $< N_{max}$, repeat Phase 1

else output G_{xy}

Phase 2: $P_{21} = G_{xy} - G_{min}$

$P_{22} = G_{xy} - G_{max}$

if $P_{21} > 0$ AND $P_{22} < 0$, output G_{xy}

else output G_{med}.

where P_{11}, P_{12}, P_{21} and P_{22} are all pixel values to be considered, G_{xy} is the window mask, $G_{min}\&G_{max}$ is the minimum and the maximum value for the mask.

- *Aplha-Trimmed Mean Filter:* The major drawback for using 'mean filter' is, it gives equal effect to all pixels in the kernel, even the noisy pixel. This can be eliminated by 'trimming' the distribution of pixel before taking the mean; by eliminating some portions of the maximum and minimum values. The Alpha-Trimmed Mean Filter [85] is a combination of mean and median filters. A kernel window say 3x3, 5x5 or 7x7 is placed in the pixel element and all the pixels are arranged in a specified manner without considering the initial and final values of the ordered set. From which, the mean is calculated from the remaining pixels. In this filter, alpha (α) denotes the number of features to be rejected.

- *Gaussian Filter:* Gaussian filter [86] gives more importance to the current pixel and then tampers the weight by varying the distance according to the Gaussian distribution. This filter is widely used for preserving the edges. The working principle of this filter consists of two stages. In the first stage, the process is performed in the horizontal direction in which the center pixel is filtered and all the pixels are multiplied by its weight and then divide altogether to grow an innovative pixel. The procedure is then reiterated in the vertical direction, in which the horizontally sort out image is handled vertically to build the absolute image.

  Two - Dimensional Gaussian equation is denoted as:

$$\frac{1}{2\pi\sigma^2} \exp\left\{\frac{-i^2 + j^2}{2\sigma^2}\right\} \tag{3.5}$$

  where

  σ represents Gaussian distribution constant

  (i,j) is the intensity value of pixel

- *Gabor filter:* Gabor filter [87] is attained by soothing a sinusoid with a Gaussian distribution. Let $gf(i, j, \theta, \phi)$ represents the Gabor filter function that must be focused at the origin at which θ denotes the spatial frequency and ϕ denotes the orientation. Gabor filters are widely used in 'texture segmentation'. The Gabor filter is defined as:

$$gf(i,j,\theta,\phi) = \exp\left[\frac{-i^2+j^2}{\sigma^2}\right]\exp(2\pi\theta x(i\cos\phi + j\sin\phi)) \tag{3.6}$$

where

σ represents Gaussian distribution constant

(i,j) is the intensity value of pixel

- *High-Pass filter:* To make an image more clear, a high-pass filter [88] might be utilized. The main purpose of this filter is to stress satisfactory element in an image. The low pass filter clears out noise; whereas the high-pass do the same in the reverse manner: it modifies the noise. If the original image does not contain that much of noise, just skip this. In general, the noise will suppress the image content and the noise is eliminated by means of high pass filtering by considering only the brightest part of the image.

  High-Pass filtering is also the reason for smoothing small fine details to be significantly extravagant. An extravagant image will look rough and strange and the pixels have dark circles around them. Even though, high-pass filtering enhances an image through sharpening, trying too firm can really degrade the image quality.

- *Laplacian filter:* A Laplacian filter [89] could be operated to highlight the edges in an image. Hence, this type of filter is generally used where the edge-detection is necessary. This process works by assigning a weighting factor with each pixel value. Before applying the filtering process, the pixels are smoothed by means of Gaussian smoothing filter in order to decrease the noise level. Both the input and output images are grey levels with varying intensities. The Laplacian filter LF (x,y) of an image with pixel intensity value PI(x,y) is specified by:

$$LF(x,y) = \frac{\partial^2 PI}{\partial x^2}\frac{\partial^2 PI}{\partial y^2} \tag{3.7}$$

- *Bilateral filter:* Bilateral filter smooths the images while maintaining edges by means of nonlinear combination of adjacent pixel values. The technique is simple, direct and non-iterative. It associates grey levels or colors based on their symmetrical familiarity and photometric relativity and gradient towards close value to isolated values in both area and range. A bilateral filter maintains the edges and smooth the colors in such a way that the human can easily recognize it. Moreover, bilateral filtering yields no shade colors beside edges in color images and reduces the color shading in the original image.

3.5 Diagrammatic Representation

The following fig.3.4 depicts the overall flow of preprocessing steps:

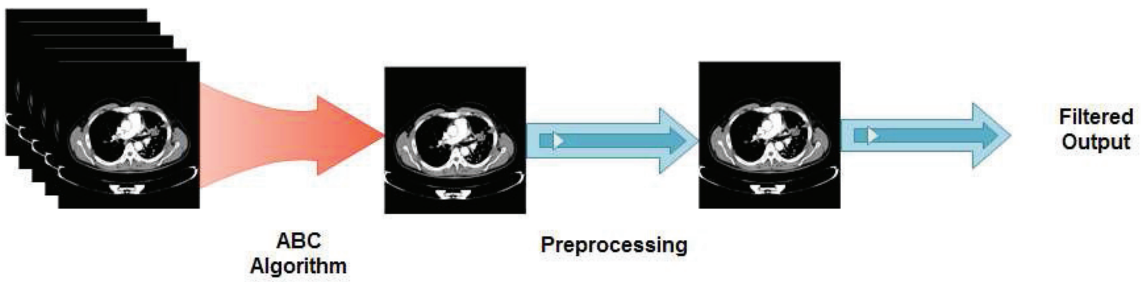


Fig. 3.4: Overall Flow Diagram of Preprocessing Stage

From the above diagram, it will clear that the initial step for preprocessing is to choose the precise slice from the pool of slices. In general, each patient has a large number of slices ranging from 150-300 based on the suggestions given by the physician. So, it is important to choose the precise slice without human intervention. Normally, expert radiologists will do the same by their experience. Once the precise slice is chosen from the ABC algorithm, it undergoes preprocessing by different types of filters. Here, different filters are used in order to get a specific filter for this application. The specific filter is one which gives high Peak-Signal to Noise Ratio (PSNR) value and low Mean-Squared Error (MSE) value. The filtered output obtained from the preprocessing stage has peak PSNR value and minimal MSE value.

3.6 Algorithm

Step 1: Initialize all the necessary values.

Step 2: Select the precise slice from the image database using ABC algorithm.

Step 3: Precede the precise image with the subsequent filters:

1. Adaptive Median filter
2. Alpha-Trimmed Mean filter
3. Gaussian filter
4. Gabor filter
5. Laplacian filter
6. High-pass filter
7. Bilateral filter

Step 4: Estimate the PSNR and MSE values for each filter.

Step 5: Choose the filter which has peak PSNR and minimal MSE values.

3.7 Experimentation and Results

The testing has been done by using CT images collected from various diagnostic centers and the collected dataset contains 418 instances of lung cancer images. The digitized images are warehoused in JPEG format with a firmness of 8 bits/plane. All images are stored in the format 512x512x8 fresh data. The original image taken from the pool of databases with different types of filters are tested, so as to remove noise and other artifacts in the images. The subsequent figure illustrates the output of the various filters.

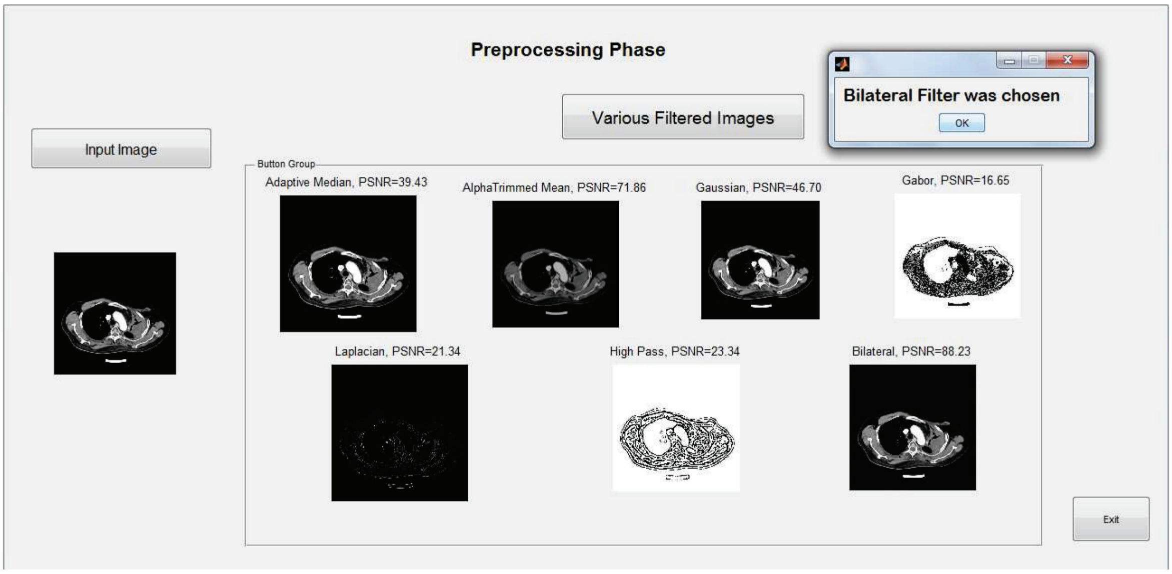


Fig. 3.5: Represents the Original Image and its Filtered Images

Fig.3.5, depicts the input slice underwent filtering using various filters such as adaptive median filter, alpha trimmed mean filter, Gaussian filter, gabor filter, high pass filter, Laplacian filter and bilateral filter. Some filters such as Laplacian and Gabor, eliminate the noise by degrading the overall image. But in the case of high-pass filter, it overwhelms the whole image and the output image is brighter than the original image.

Table 3.1: PSNR and MSE values of different filters

Filters Name	PSNR VALUE	MSE VALUE
Adaptive Median filter	39.4309	29.33109
Alpha-Trimmed Mean filter	71.86155	0.016638
Gaussian filter	46.70281	17.08423
Gabor filter	16.65061	547
High-Pass filter	23.34334	348
Laplacian filter	21.34006	557
Bilateral filter	88.22711	0.000379

The Table 3.1 predicts that the bilateral filter yields peak PSNR value and minimal MSE value followed by Alpha-trimmed mean filter. Here, the Gabor filter yields the least PSNR value with maximum MSE values followed by the Laplacian filter.

3.8 Discussion

Image preprocessing is a label, specified for performing certain tasks in an image at the least level of perception with the intention of improving the worth of the image that defeat the undesired falsification or enrich some image features that is significant for further processing. Besides the various image quality assessment techniques [90], [91], the most plain and open techniques used is Peak Signal to Noise Ratio (PSNR) and Mean Squared Error (MSE) values. For more than one decade, the degree of the image features are measured using the PSNR and MSE values, because they characterize the overall representation of the image.

3.8.1 Mean Squared Error (MSE)

Mean Squared Error is assessed to compute the modification between the pixel values in the original image with that of the estimated image. A known noiseless monochrome image MI of a x b and its approximation η, and the MSE value is defined as:

$$MSE = \frac{1}{ab}\sum_{x=0}^{a-1}\sum_{y=0}^{b-1}[MI(x,y) - \eta(x,y)]^2 \tag{3.8}$$

3.8.2 Peak Signal-to-Noise Ratio (PSNR)

The Peak Signal to Noise Ratio is the modification among the extreme possible signal and the debasing noise that disturb the illustration of an image. The PSNR values are usually defined as a decibel scale. If the PSNR value is high, it means that the quality of the image is also high.

$$PSNR = 20\log_{10} MAX_x - 10\log_{10} MSE \tag{3.9}$$

Here, MAX_x represents the maximum value of the image. In both MSE and PSNR x,y represents the pixel intensity.

3.9 Conclusion

In the preprocessing step, from the acquired CT image database a single slice is chosen by means of ABC algorithm. The single slice is preprocessed to eliminate the noise and other artifacts by means of various filters. After preprocessing, the analysis is carried out using both linear and nonlinear filters that are used for further experimentation. The best choice of the filter is taken away in terms of high PSNR and low MSE values. As the Bilateral filter yields the expected result, it is used as the filtering medium for the forthcoming process.