Medical Image Processing

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Chapter 2: Image Examination

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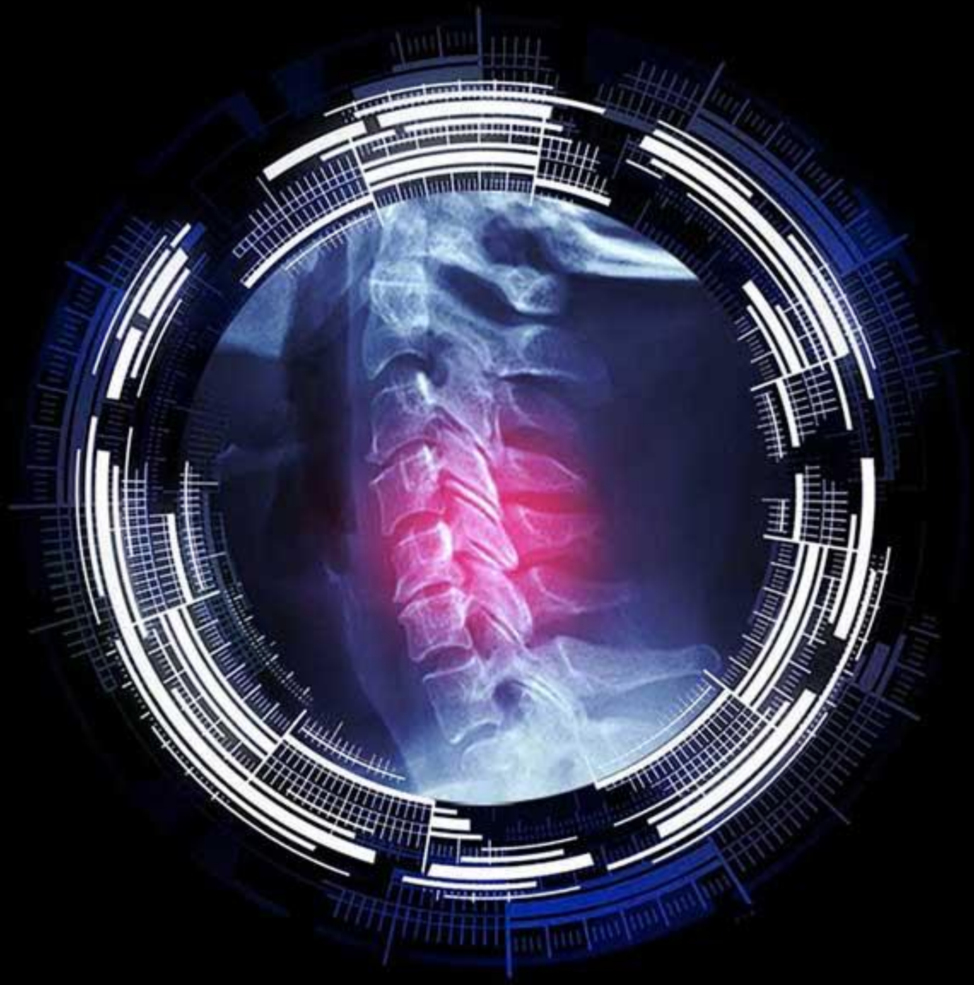
- The universal disease diagnostic process followed in hospitals involves (i) personal assessment by a skilled physician and (ii) recording and assessment of illness and its symptoms using a specific protocol. In most cases, the imaging procedures are extensively considered to assess the illness in organs by means of a suitable or preferred image modality.
- The preliminary level, which intends to reveal the body function with imaging, is known as the raw or unprocessed image. These images are contaminated with artifacts, along with the normal segment to be examined. To eliminate the artifact and to enhance the image segment, it is important to implement an image pre-processing technique which improves the condition of the image. This section discusses primarily used image enrichment techniques to pre-process the raw recorded image



2.1 Clinical Image Enhancement

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- Once the image is recorded using a preferred protocol, it is treated by procedures such as image enhancement, pre-processing, post-processing, and examination.
- These pre-processing techniques enhance the medical images recorded to aid in the examination of abnormalities.
- According to the image registration, the picture is classified as two-dimensional (2D) or three-dimension (3D). Normally, the processing actions existing for 2D imagery are moderately straightforward compared to 3D.

2.1 Clinical Image Enhancement

- In some circumstances, the information existing in the untreated images are difficult to analyze. Therefore, pre-processing and post-processing techniques are proposed and executed by researchers.
- The implemented picture processing methods can help develop the state of the unprocessed image with a selection of methodologies such as contrast-enhancement, edge-detection, noise-removal, filtering, fusion, thresholding, segmentation, etc.
- Most of the existing augmentation events work well for greyscale pictures compared to RGB-scale pictures.

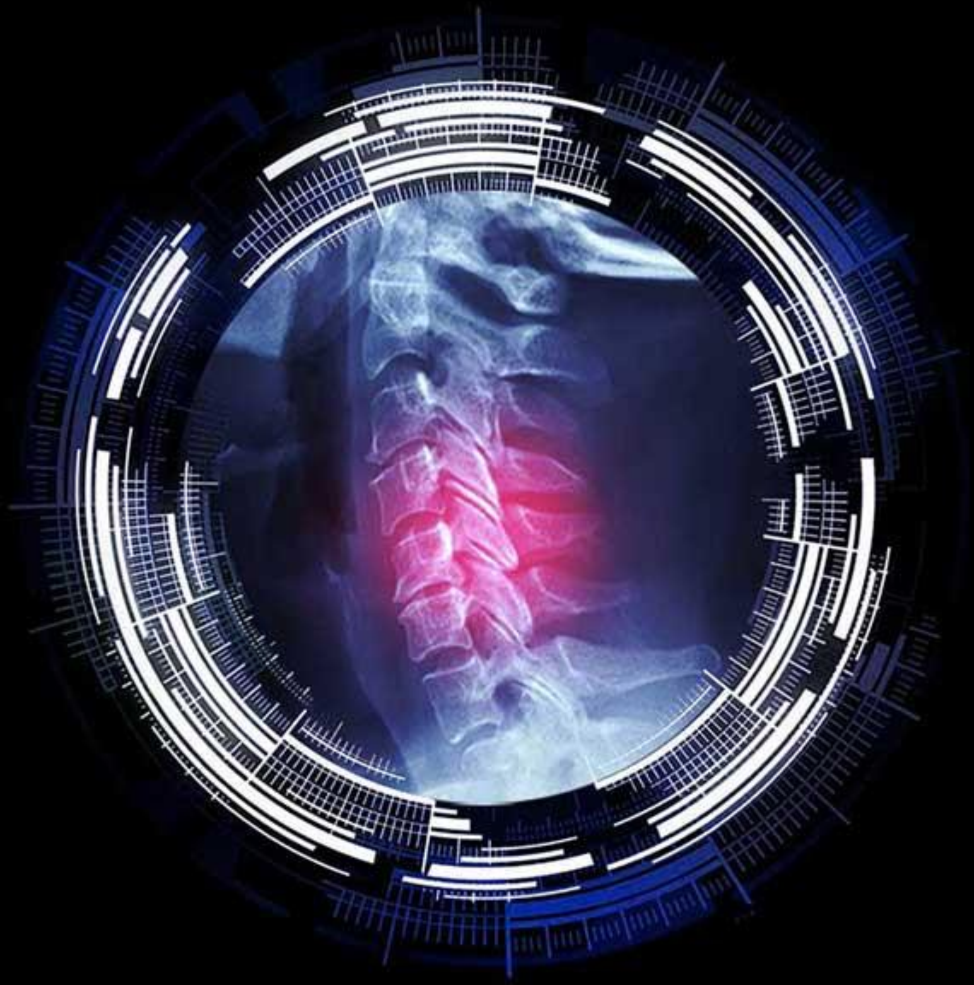
2.2 Importance of Image Enhancement

2.2 Importance of Image Enhancement

- Initially, images recorded using a chosen image modality is referred to as the unprocessed image. Based on what is required, these raw images may be treated with a specific image conversion or enrichment technique.
- The digital images recorded using the well-known imaging methodologies are associated with various problems. Before further assessment, it is essential to improve information available in the image.

2.2 Importance of Image Enhancement

- Presently, recorded digital images are processed and stored using digital electronic devices. To ensure eminence, a particular image modification procedure is needed to convert the raw image into the processed image. Enhancement procedures, such as (i) artifact removal, (ii) filtering, (iii) contrast enrichment, (iv) edge detection, (v) thresholding, and (vi) smoothing, are some common procedures implemented in the literature to convert the unprocessed image.
- Image enhancement is essential to improve the visibility of recorded information. Also, extracting recorded information from enhanced images is easier compared with information from unprocessed images.



2.3 Enhancement Techniques

2.3 Enhancement Techniques

- Most recent medical imaging systems are computer-controlled systems. Thus, the images attained by means of imaging schemes are digital.
- The excellence of an image is judged based on the visibility of Section-of-Interest (SOI) and the distinct variation between the background and the SOI.
- The picture recorded by a particular imaging mechanism needs to be processed to convert it into a working image. This procedure is essential and a complex task when the image SOI is associated with unwanted noise and artifact.

2.3.1 Artifact Removal

- Artifact removal is essential to divide the picture into a number of sub-sections based on an optimal threshold value. The artifact elimination technique usually implements a morphological filter along with a clustering approach such that the image pixels are ordered, grouped to extract a variety of information based on the selected threshold value.
- This approach is widely implemented in medical image processing applications to remove artifacts in the 2D slices of MagneticResonance-Image (MRI) and Computed-Tomography (CT). In this section, the 2D brain MRI slice of the MRI and the CT scan slice are considered to demonstrate the performance of the selected threshold filter

2.3.1 Artifact Removal

Figure 2.1 presents the structure of the procedure.

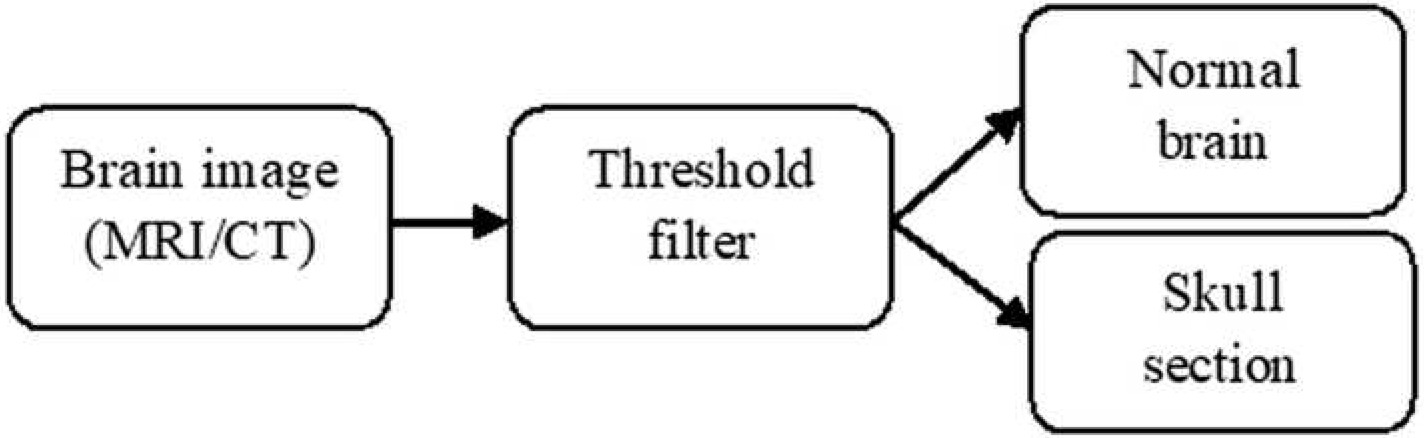


FIGURE 2.1 Implementation of Threshold-Filter for ROI and Artifact Separation.

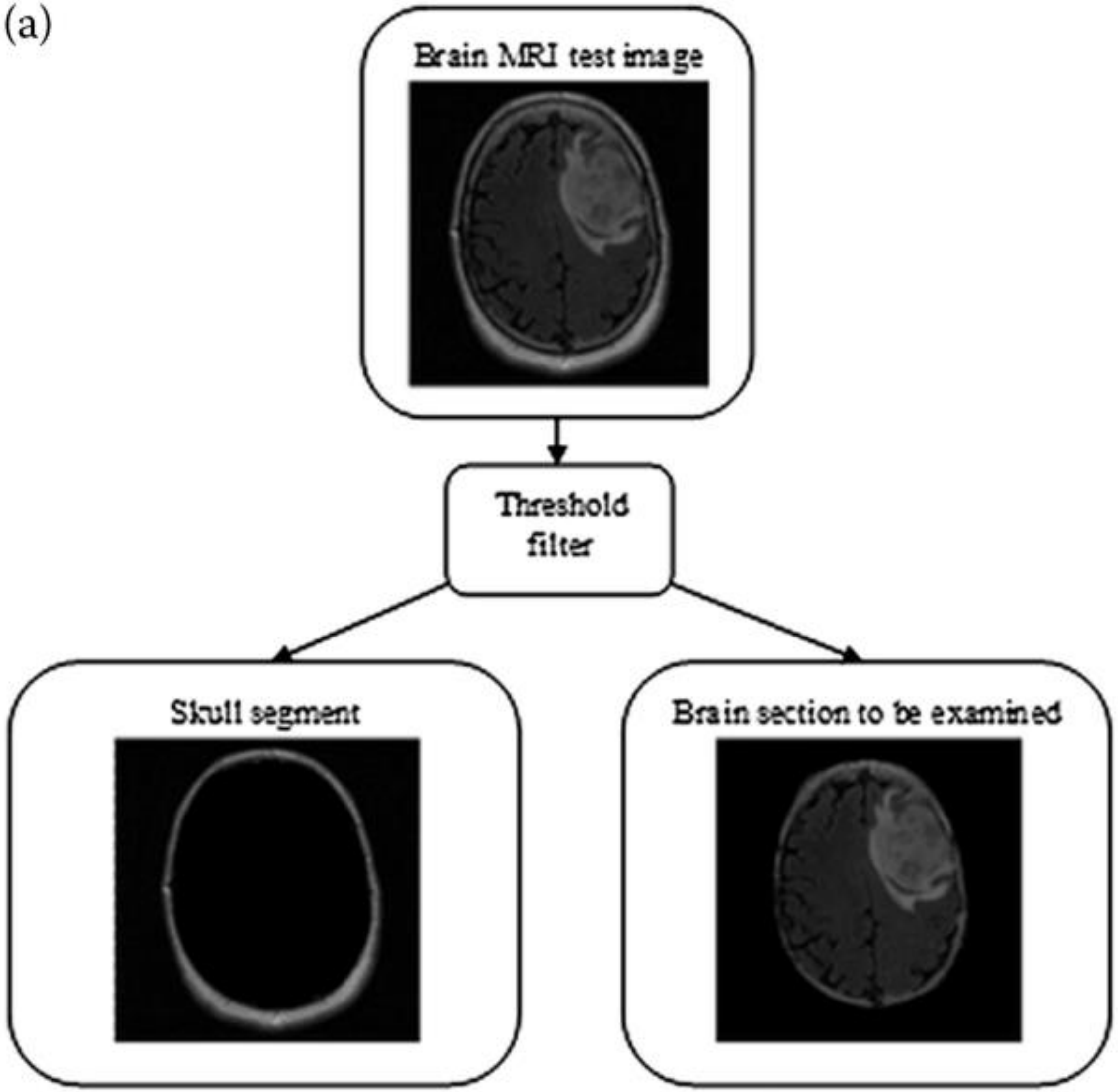
2.3.1 Artifact Removal

- Threshold is a type of filter used to pre-process the medical images recorded with MRI or CT. This separates the brain MRI slices into skull section and the normal brain anatomical regions. After pre-processing, the test image with the recommended technique is further considered for the examination process. Literature confirms that the pre-processed medical images (MRI as well as CT) with the filter being implemented help attain better results compared to the unprocessed image.
- **Advantages**: Threshold filter separates ROI and artifact and it diminishes the difficulty in assessing the raw image.
- **Limitations**: The major restriction of the threshold filter is the choice of optimal threshold, which segregates the raw image into two sections. In most cases, the threshold choice is done physically with a range of trials. Experiment-based method is a time-consuming practice which works only on greyscale images.

2.3.1 Artifact Removal

Figure 2.2 (a) and (b) illustrates the results attained by the brain MRI and the lung CT scan images, respectively

(a)

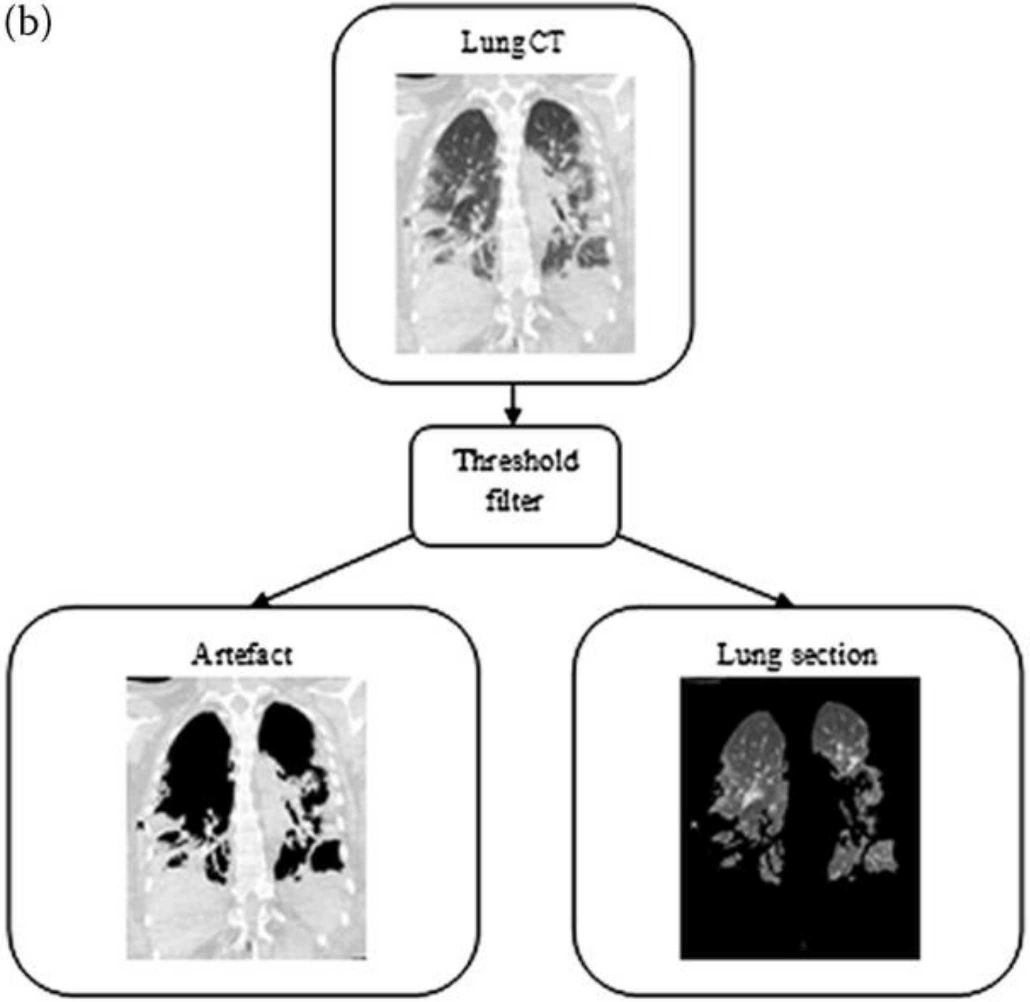


Brain MRI assessment

2.3.1 Artifact Removal

Figure 2.2 (a) and (b) illustrates the results attained by the brain MRI and the lung CT scan images, respectively

(b)



Lung CT scan slice examination

FIGURE 2.2 Experimental Results of the Threshold Filter.

2.3.2 Noise Removal

- In conventional digital image processing, the filter employed through a selected practice and a favorite order is to allow/block the image information based on the frequency value. In this operation, unnecessary pixels accessible in the digital picture is removed/blocked with a preferred filter based on pixel operation.
- Figure 2.3 presents the arrangement of the conventional filter, which eradicates noise from the digital gray/RGB image. Figure 2.4 presents the results attained for a 2D brain MRI slice. In this work, the noise filter is employed to eliminate the noise (Salt & Pepper) associated with the test image. Once the noise is eliminated, the filtered image becomes clear for further processing. Results obtained in various image modalities are depicted in Figure 2.5 which may be gray or RGB in nature.

2.3.2 Noise Removal

- Advantages: The image filter removes surplus pixels in the chosen digital representation. It can also be used as an essential pre-processing system for the medical images of varied modalities.
- Limitations: Attainment of a selective image filter to assess the image is relatively time-consuming as it processes the raw images stained with noise.

2.3.2 Noise Removal

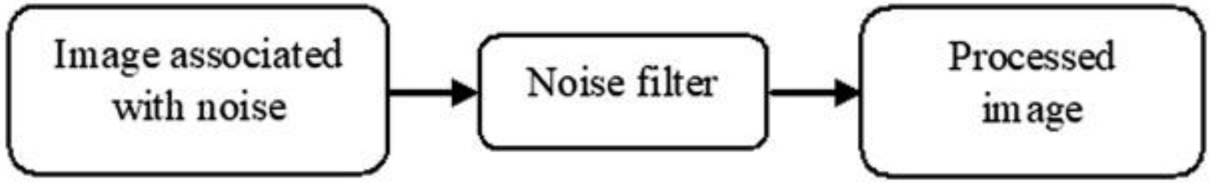


FIGURE 2.3 Implementation of a Filter to Eliminate the Associated Noise.

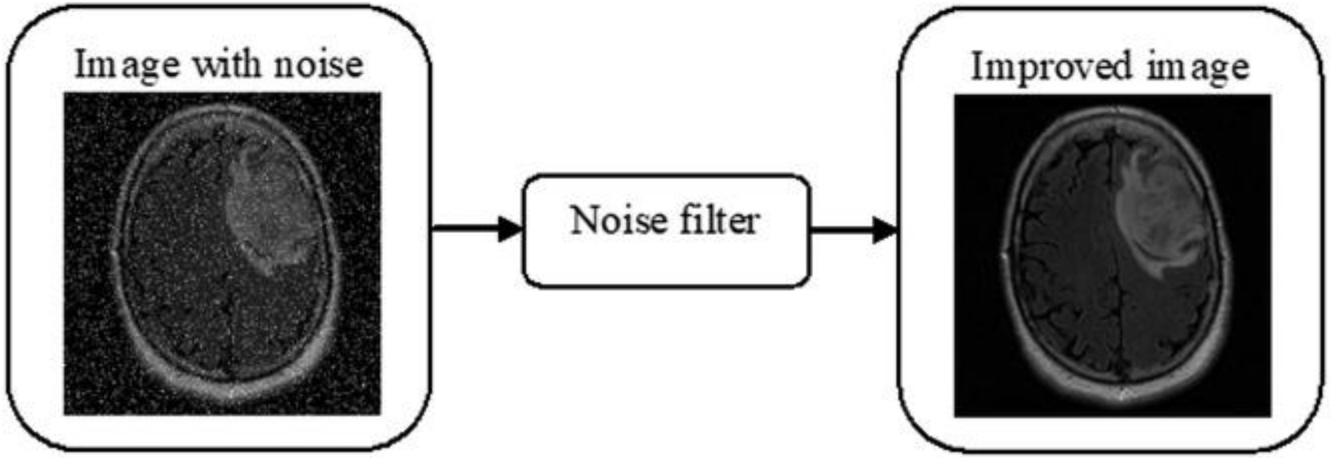


FIGURE 2.4 Salt and Pepper Noise Removal Implemented on a Brain MRI Slice.

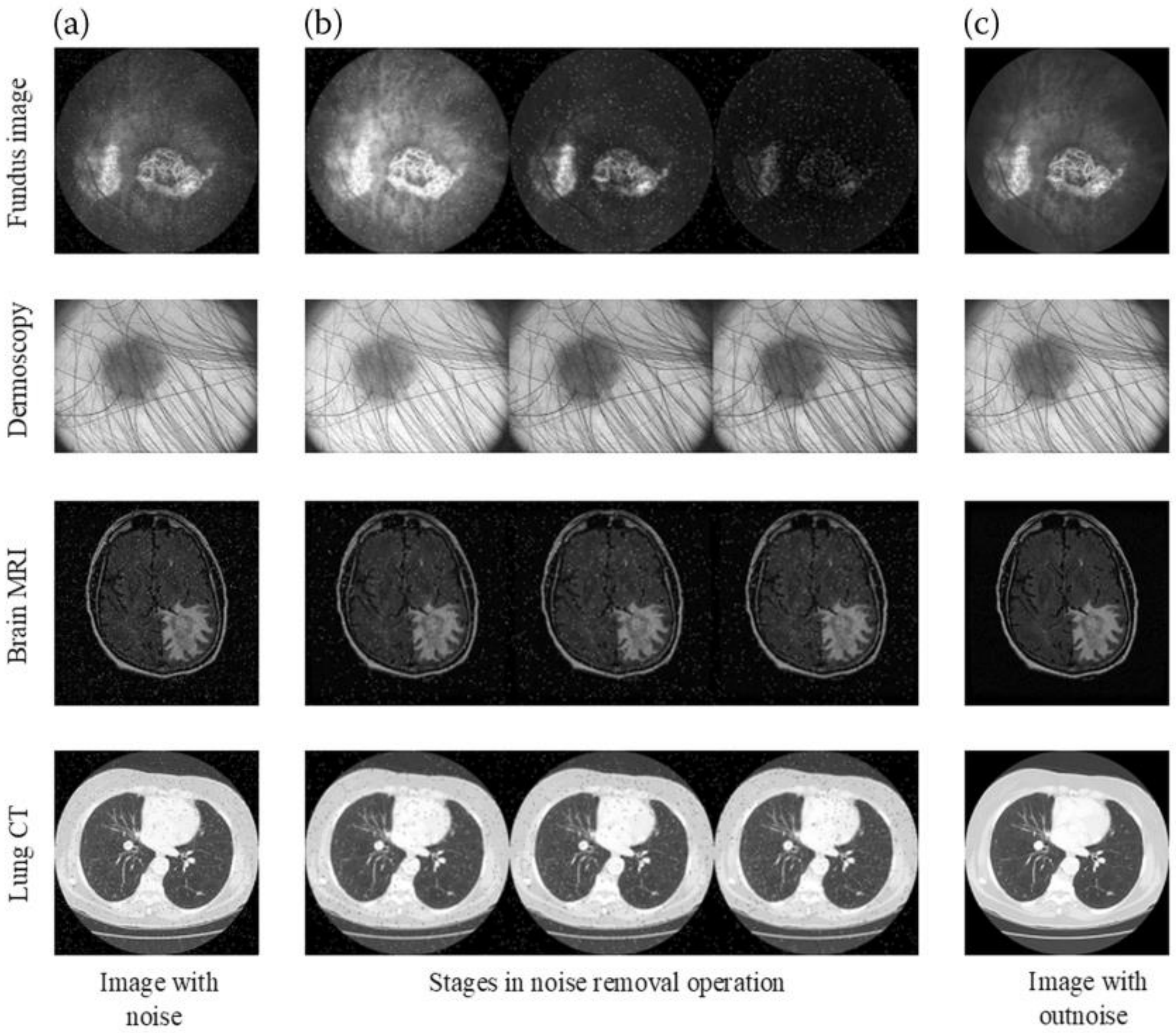


FIGURE 2.5 Removal of Noise in Gray/RGB Scale Image.

2.3.3 Contrast Enrichment

- Information present in the greyscale image is usually poor compared with that of the RGB-scale image. In greyscale images, enhancing the ROI with respect to its surroundings is a critical task, thus a number of Image Processing Schemes (IPS) are proposed and implemented by the researchers to improve visibility. Contrast enhancement is one of the widely adopted techniques in medical image processing. This can be implemented in a number of ways. The schemes, such as histogram equalization, Color-map tuning and Contrast-Limited-Adaptive-HistogramEqualization (CLAHE), are some of the procedures considered to enhance greyscale images

2.3.3 Contrast Enrichment

- **Advantages:** Image contrast enhancement is a common technique and requires low computational effort during implementation.
- **Limitations:** This technique is used throughout the preliminary-level picture augmentation process and in most of image processing. It is an optional practice and the images connected with noise will not offer expected results with this procedure.

2.3.3 Contrast Enrichment

Figures 2.6 and 2.7 depict the structure of the IPS and its related results, respectively

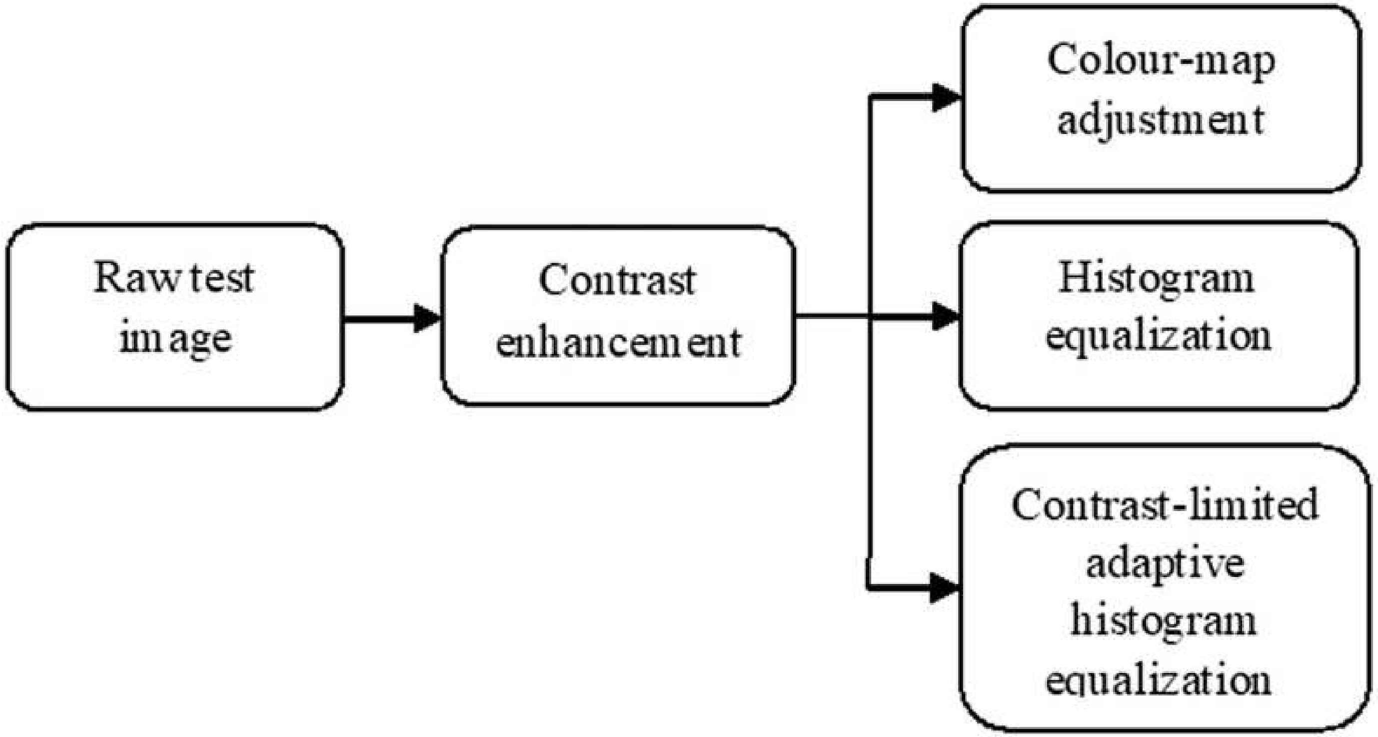


FIGURE 2.6 Commonly Considered Contrast Enhancement Methods.

2.3.3 Contrast Enrichment

Figures 2.6 and 2.7 depict the structure of the IPS and its related results, respectively

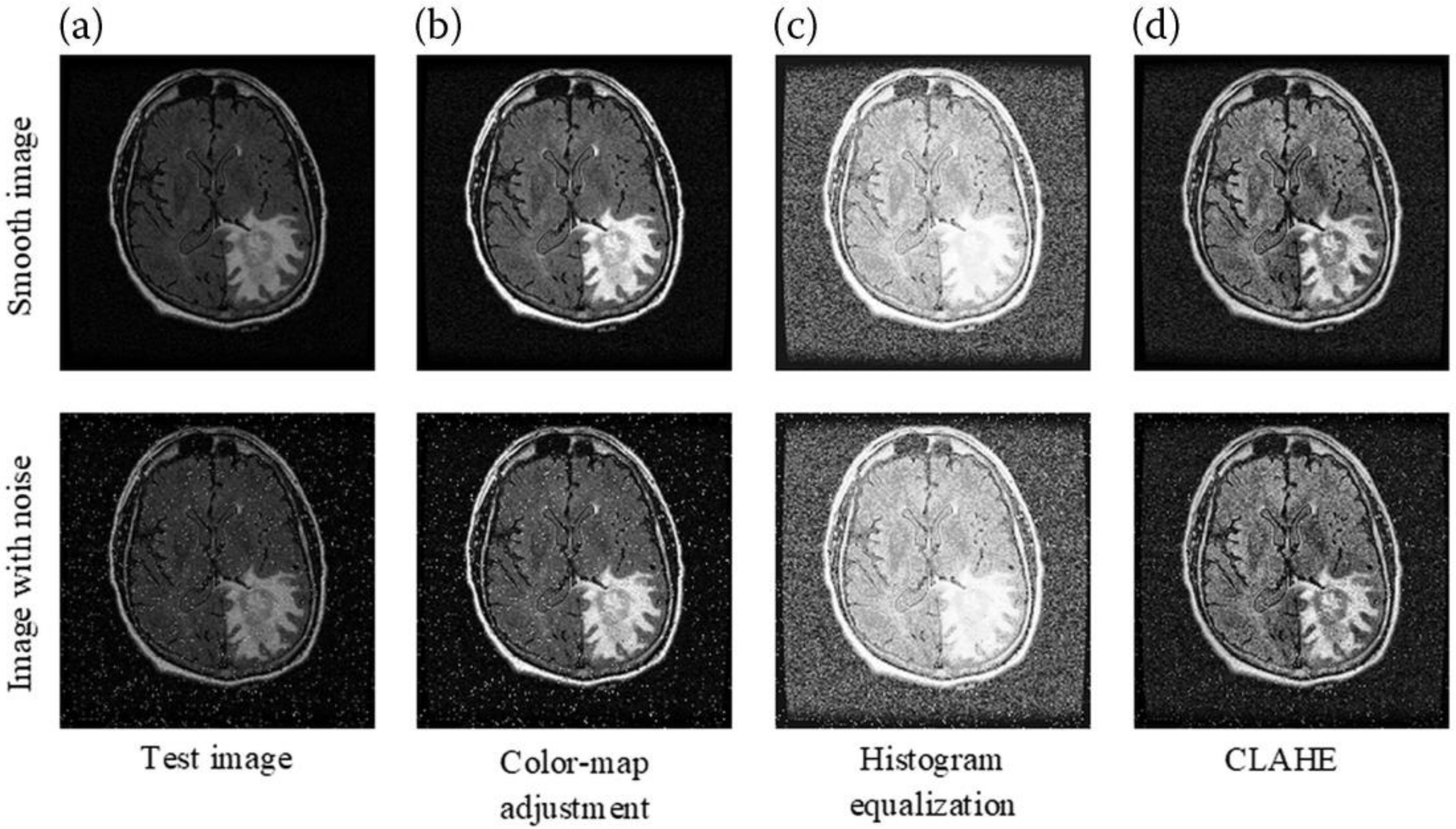


FIGURE 2.7 Contrast Enhancement of the Brain MRI Slice to Enhance the Tumor Section.

2.3.3 Contrast Enrichment

The various shapes of the gray-level histogram of the brain MRI for various techniques are depicted in Figure 2.8

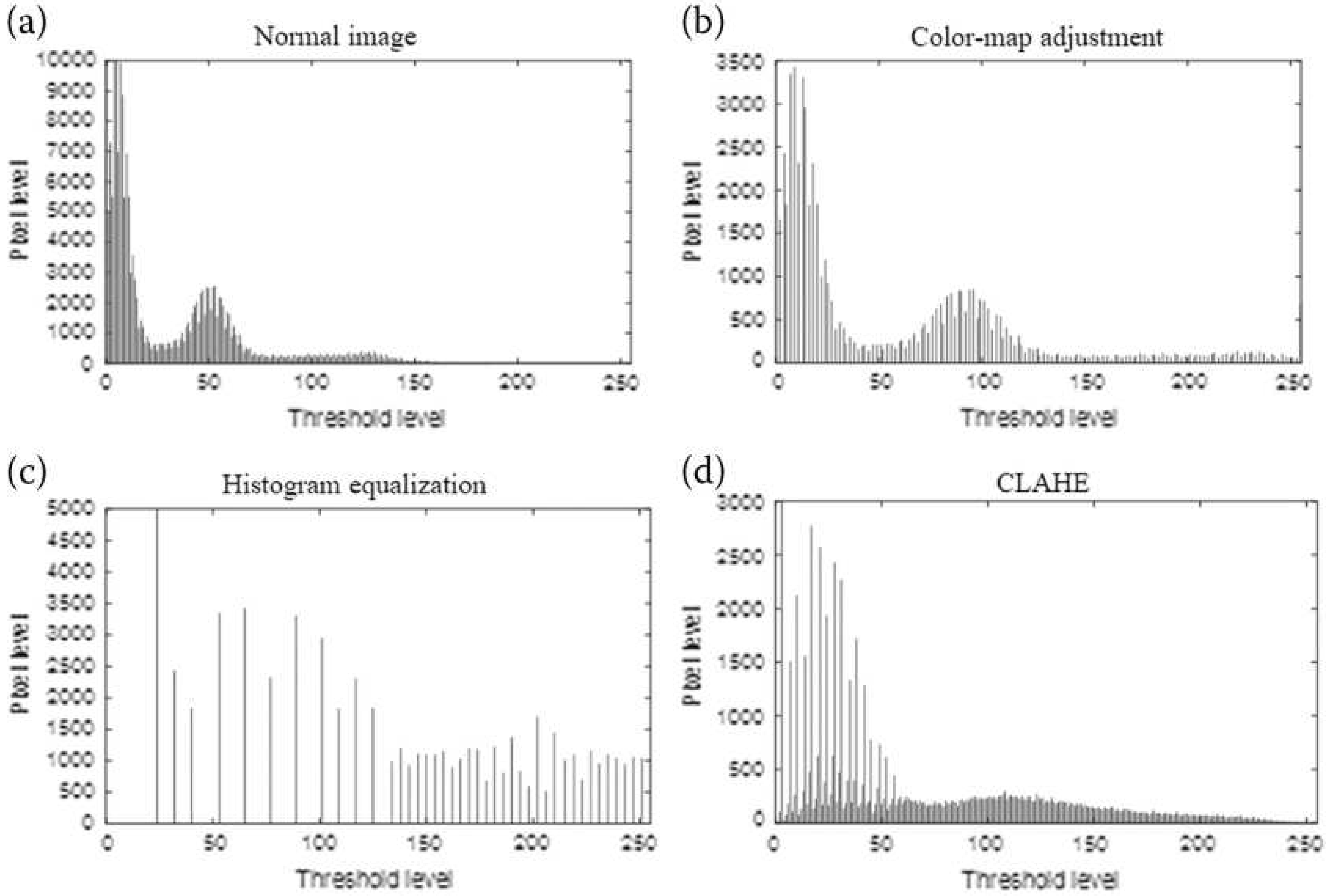


FIGURE 2.8 Variation of Pixel Distribution in Gray-Level Threshold Based on the Implemented Contrast Enhancement Technique.

2.3.3 Contrast Enrichment

Contrast enhancement employed for other gray/RGB-scale test images with and without noise is projected in Figure 2.9

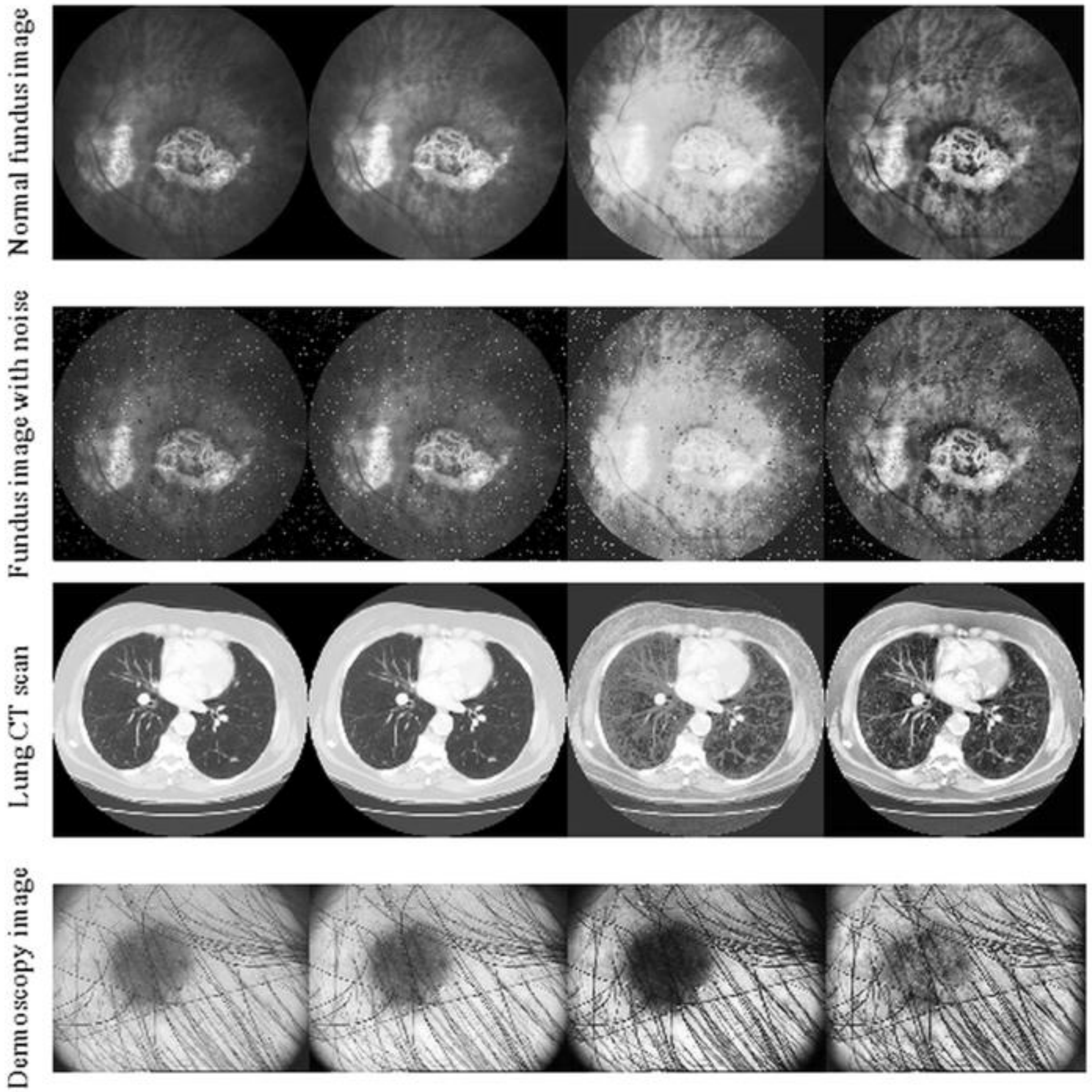


FIGURE 2.9 Contrast Enhancement Technique Implemented on a Class of Images.

2.3.4 Edge Detection

- This process is used to outline the borders of the SOI existing in the test picture. In the literature, a number of edge detection methods have been listed. The CannyEdge-Detector (CED) is generally a popular method starting in 1986.
- This employs a multi-stage algorithm to recognize a broad collection of edges in the images. CED is used to extract precious structural information from the images but considerably diminishes the quantity of information to be investigated.

2.3.4 Edge Detection

The general circumstance for edge recognition includes:

- Recognition of a border with smaller error rate by accurately finding numerous edges existing in the trial image.
- The perimeter tip predictable from the operator should accurately be confined to the heart of the border.
- The perimeter of the picture should only be recognized once, and the image noise should not form fake boundaries.

To achieve these points, Canny implemented calculus of variations to optimize the operation.

2.3.4 Edge Detection

- Sobel is another common type of edge detection procedure adopted in the image processing literature.
- Advantage: Implementation of edge discovery is necessary to identify the boundary and the texture of the picture under study.
- Limitation: The edge detection process necessitates complex procedures to recognize the boundary of the picture and this practice will not offer fitting outcomes when RGB-scale images are considered.

2.3.4 Edge Detection

- The edge detection result attained with Sobel and Canny on a CT image is presented in Figure 2.10. It is noticed from Figure 2.10 (b) that the investigational result of the Canny is superior to Sobel and the selection of particular edge discovery can be chosen as per the expertise of the operator.

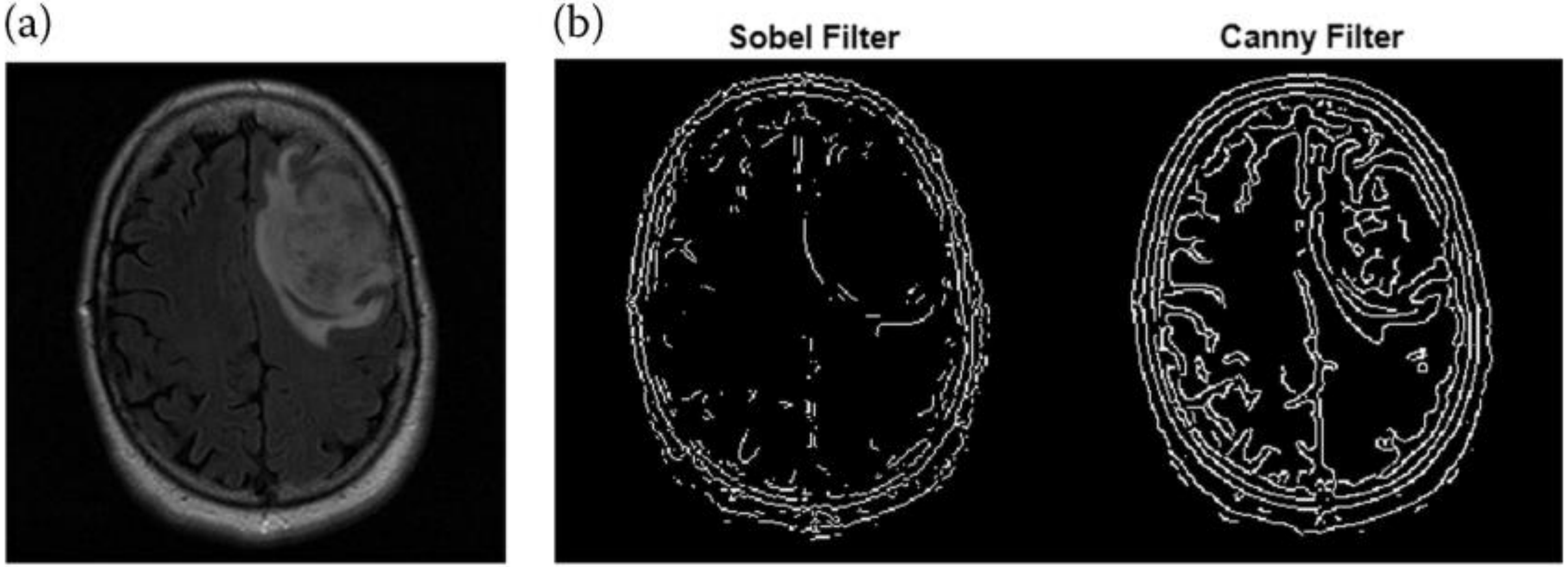


FIGURE 2.10 Result Attained with the Edge Detection Technique. (a) Test Image, and (b) Attained Result with Sobel and Canny Filters.

2.3.5 Restoration

- Haziness in medical images arises due to various reasons. This problem degrades the information in the images.
- This is a common problem that can be overcome by performing the imaging procedure once again. During the crucial image recording process, retaking of the image is not possible; further, image recording requires a considerable number of procedures and precautionary measures.
- Hence, it is necessary to implement image restoration techniques which help to correct/remove the haziness in the medical image. The restoration technique will compute the major pixels in the image and fix the distortion to get a better restoration.

2.3.5 Restoration

- The sample test images considered for demonstration is depicted in Figure 2.11 and the corresponding results are depicted in Figure 2.12. Figure 2.12 (d) confirms that the considered restoration technique helped to correct the test image of various modalities

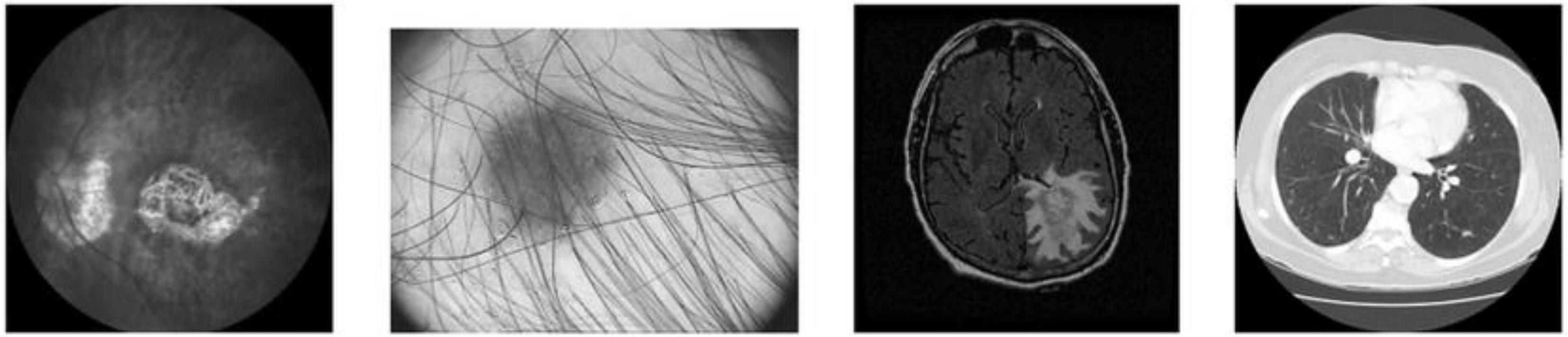


FIGURE 2.11 Sample Test Images for the Assessment.

2.3.5 Restoration

Figure 2.12 (d) confirms that the considered restoration technique helped to correct the test image of various modalities

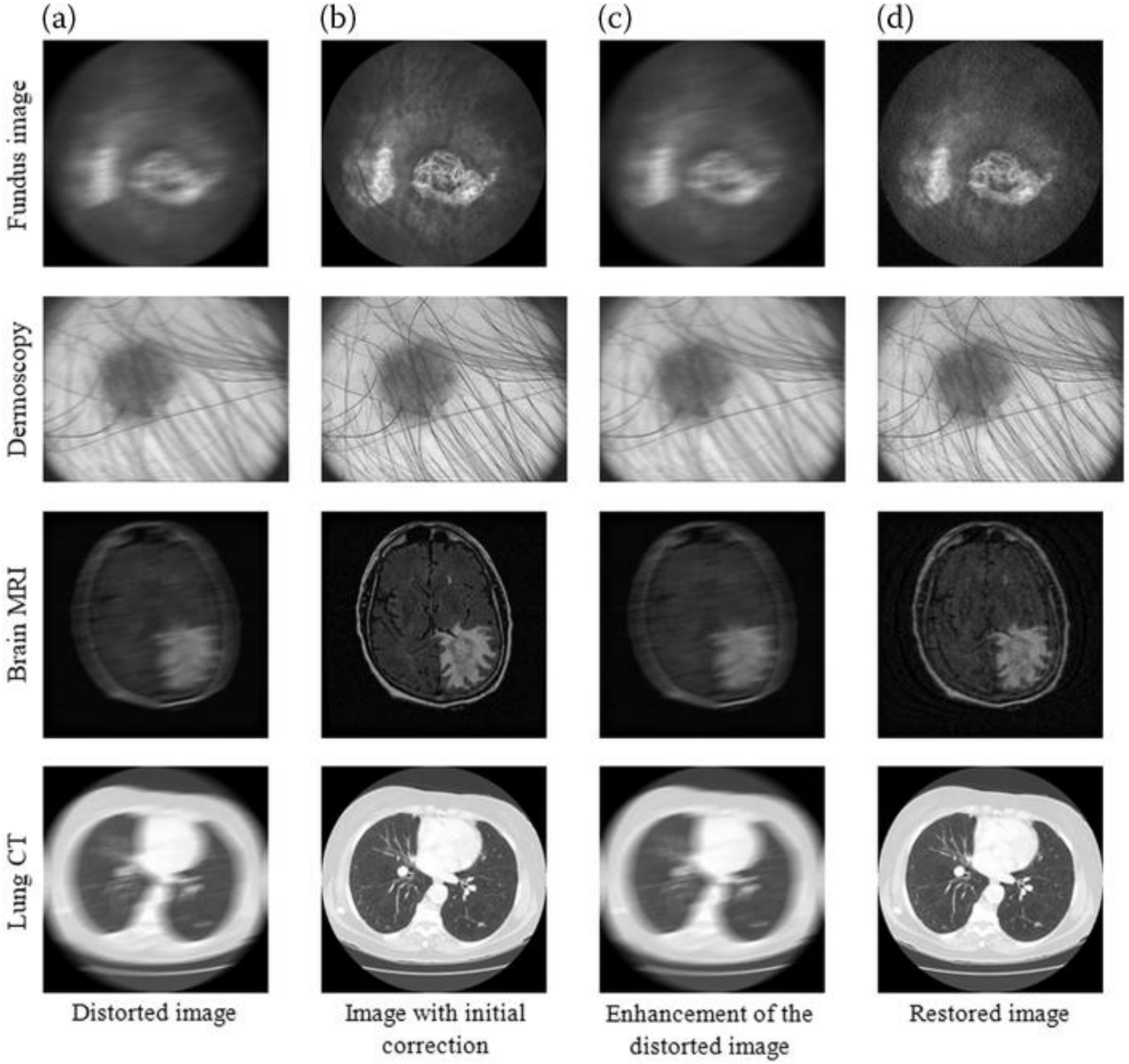


FIGURE 2.12 Result Attained

2.3.6 Color Space Correction

- Color space correction is an essential procedure implemented to regulate the R, G, and B pixels in RGB-scale pictures to improve the SOI of the test picture.
- In this work, the pixel distribution of the R/G/B thresholds is adjusted manually or through a computer algorithm to enhance the results.

2.3.6 Color Space Correction

The chosen test image and the results obtained after the color space correction operation is depicted in Figure 2.13.

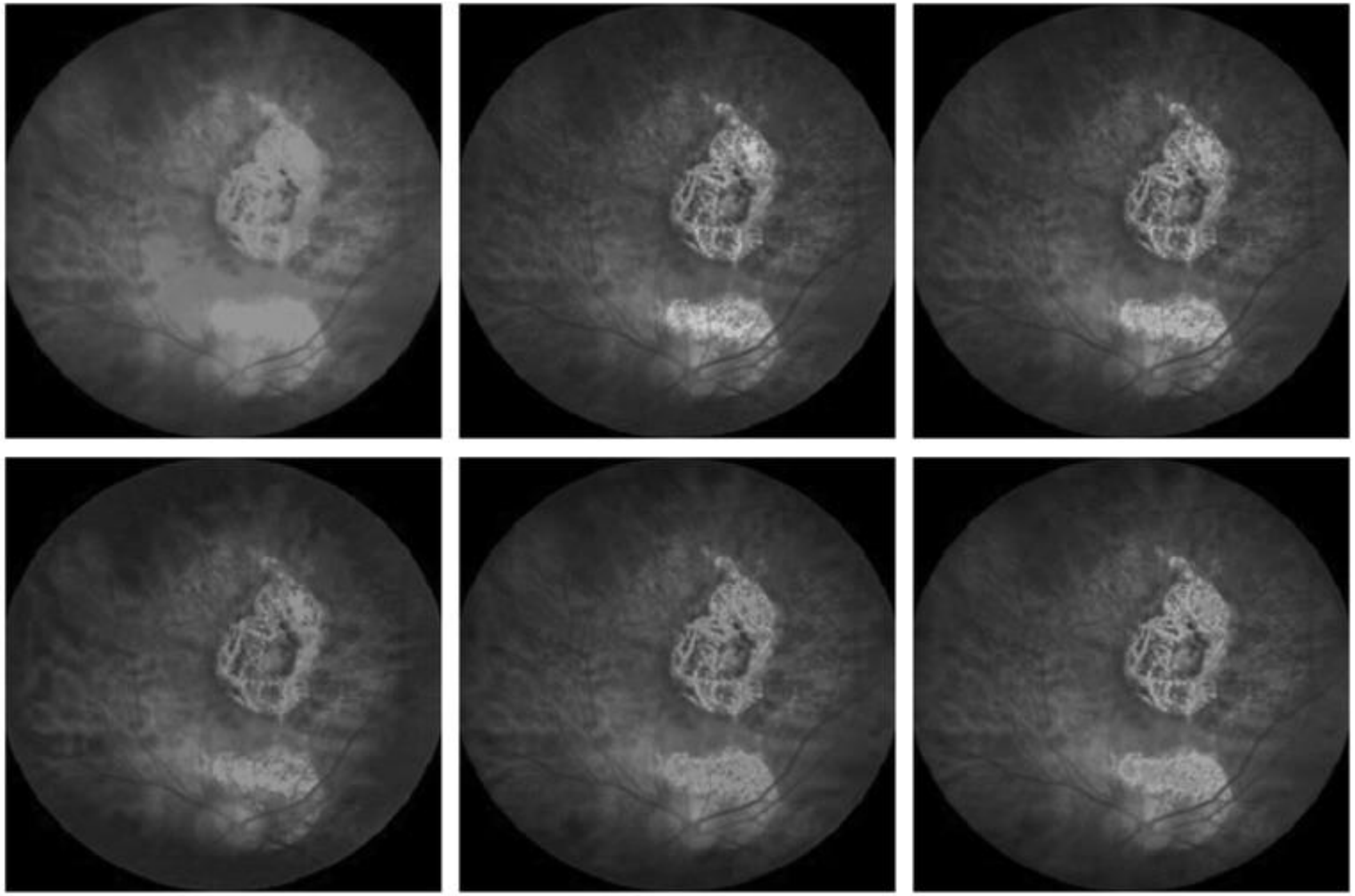


FIGURE 2.13 The Results Achieved Using the Color Space Correction Practice.

2.3.7 Image Edge Smoothing

- During automatic recognition and classification operations, texture and silhouette features extracted from the picture play a fundamental function. Before extracting the surface features from a picture, it is necessary to treat the raw image with preferred picture normalization procedures.
- The image's surface smoothing based on a chosen filter is widely adopted to improve the texture features. Earlier works confirmed that the Gaussian-Filter (GF) practice can be employed to recover the surface and the perimeter features of the greyscale picture for a selected dimension. Further, one of the previous research confirmed that the GF with varied scale (φ) can provide enlargement of texture pattern vertically and horizontally

2.3.7 Image Edge Smoothing

- The conventional Gaussian operator for a 2D image is presented as in Equation (2.1):

$$U(x,\ y) = \frac{1}{2\pi\phi^2} e^{-\left[\frac{x^2+y^2}{2\phi^2}\right]} \qquad (2.1)$$

where ϕ = standard deviation and $U(x, y)$ = Cartesian coordinates of the image. By altering ϕ, imagery with diverse edge enhancements can be created

- Laplacian of Gaussian (LOG) function as a filter helps identify edges by computing the zero-crossings of their second derivatives as observed in Equation (2.2)

$$\nabla^2 U(x,\ y) = \frac{d^2}{dx^2} U(x,\ y) + \frac{d^2}{dy^2} U(x,\ y) = \frac{x^2 + y^2 - 2\phi^2}{2\pi\phi^6} e^{-\left[\frac{x^2+y^2}{2\phi^2}\right]} \qquad (2.2)$$

2.3.7 Image Edge Smoothing

Figure 2.14 presents the selected brain MRI and the related experimental results. Figure 2.14 (a) presents the horizontally smoothened MRI slice for a chosen value of φ = 30 and Figure 2.14 (b) depicts the vertically smoothened image where φ = 300.

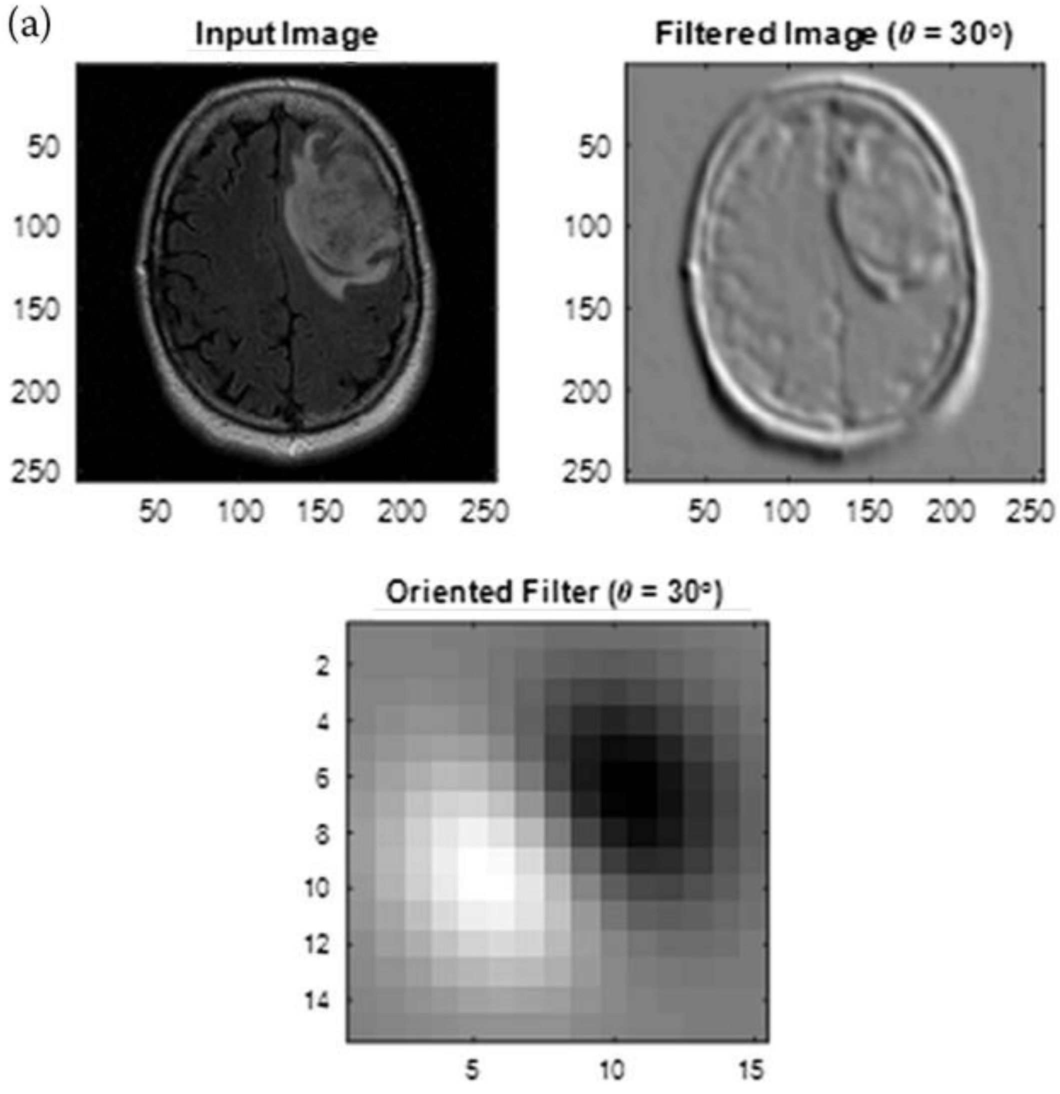


Image with horizontal smoothening

2.3.7 Image Edge Smoothing

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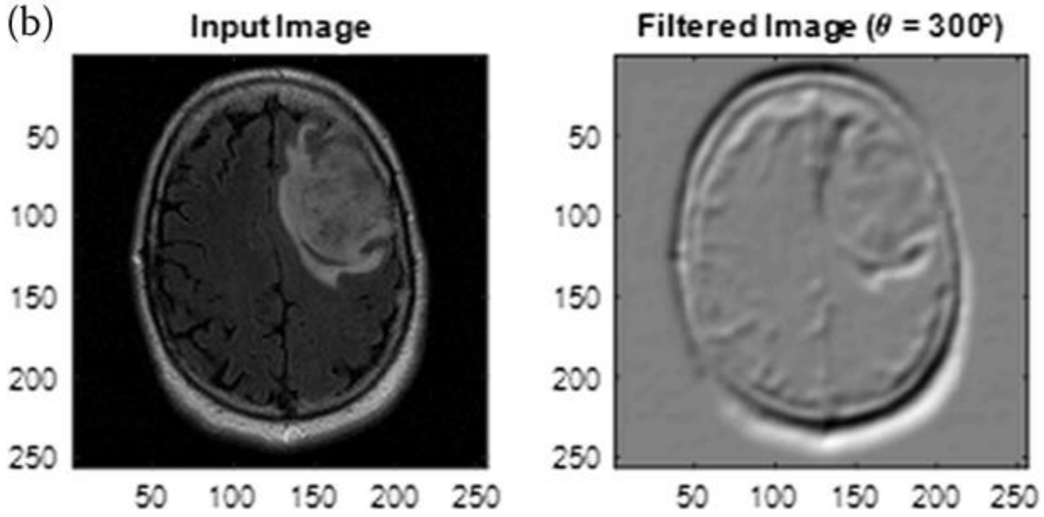


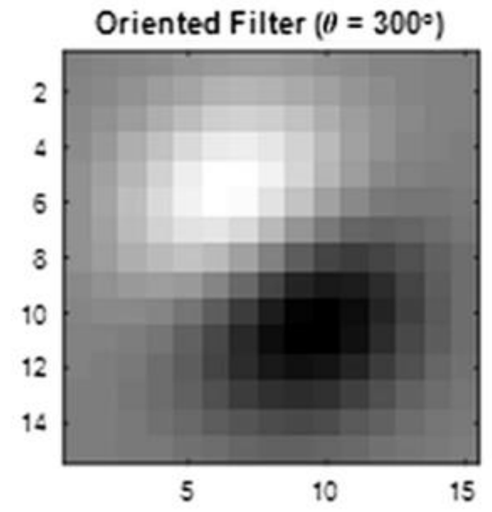


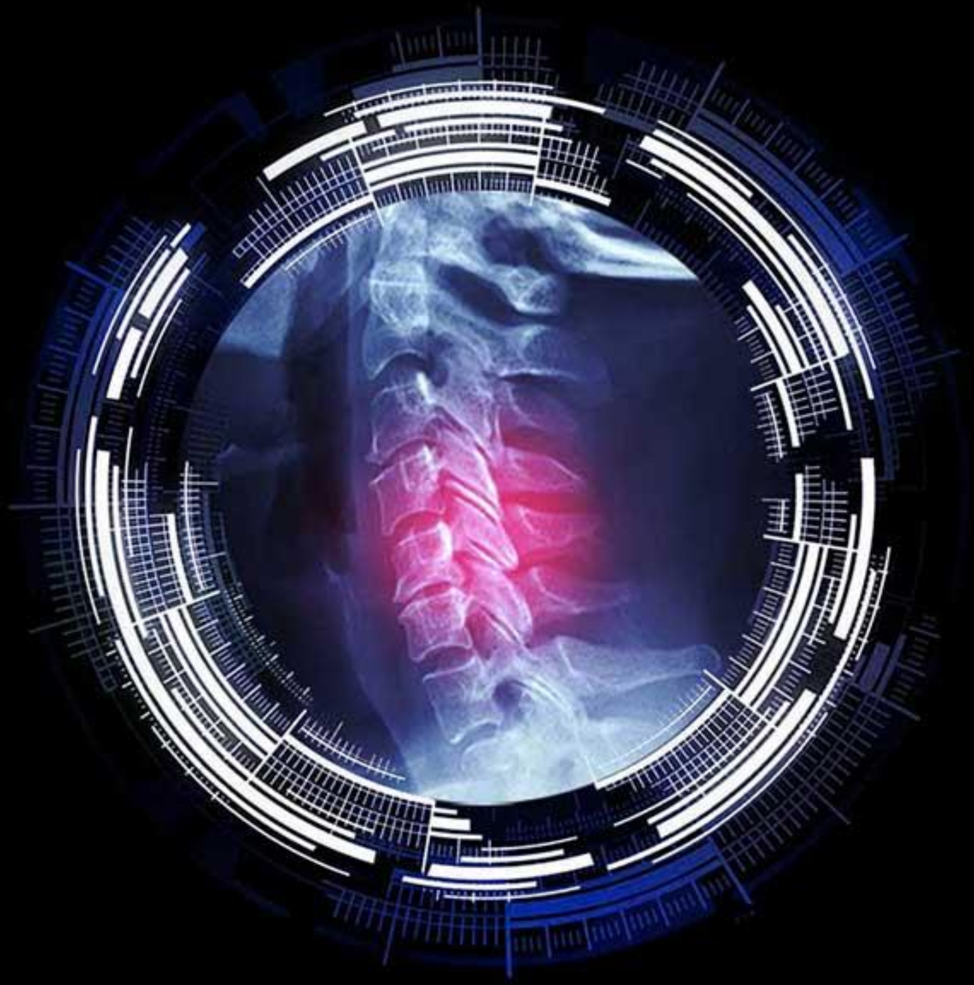
FIGURE 2.14

Results Attained with Gaussian-Filter-Based Enhancement.

Image with vertical smoothening

2.3.7 Image Edge Smoothing

- **Advantages:** GF-based practices are used to regularize the surface and perimeter of the greyscale images of varied aspects. Further, this scheme can be used to create various edge as well as texture patterns based on the chosen ϕ. The GF also supports a wide range of edge and texture detection procedures. Canny edge discovery practice employs GF to recover the edges of the test image.
- **Limitations:** The information present in the GF filter treated test image can be examined only with a selected image examination practice as the information cannot be examined by physical operators. Hence, this image assessment can be used only when a computer-assisted algorithm is employed to detect/classify the picture based on its SOI's edge/texture features.



2.4 Recent Advancements

2.4 Recent Advancements

- Recently, a considerable number of computer algorithms have been developed to support a variety of image examination operations. The computerized image processing (i) supports semi-automated/automated examination, (ii) works well for greyscale/RGB images, (iii) can be used to implement a variety of soft-computing techniques, and (iv) the results of these methods can be stored temporarily or permanently based on the requirement.
- The computerized algorithms helped achieve a variety of image assessment procedures to improve the clarity and the information in the picture irrespective of its color, size, and pixel distribution. Further, a number of software have been developed to maintain the computerized image processing procedures without compromising its excellence and the throughput with these procedures are better compared to operator-assisted schemes.
- Due to its qualities, computer-assisted procedures are employed in a variety of image-based assessment schemes to perform necessary operations such as artifact removal, contrast enhancement, edge detection, smoothing, and thresholding. Further, the availability of heuristic algorithms and its support towards image processing has helped to expand and implement different machine-learning and deep-learning techniques to process a selection of images with a preferred pixel dimension.

2.4.1 Hybrid Image Examination Technique

- Recent image processing literature confirms the need for hybrid image examination techniques to achieve better disease detection using the test images of a chosen modality.
- The hybrid image examination technique combines all the possible image processing procedures to improve detection accuracy.
- The common structure of the hybrid-image examination procedure implemented with a chosen heuristic algorithm is depicted in Figure 2.15. The main task of this structure is to implement a particular image enhancement technique to improve the visibility of the SOI. Then, a chosen segmentation procedure is implemented to extract the infected section from the test image. Finally, the extracted information is verified by a doctor, who then implements treatment based on the severity.

2.4.1 Hybrid Image Examination Technique

The common structure of the hybrid-image examination procedure implemented with a chosen heuristic algorithm

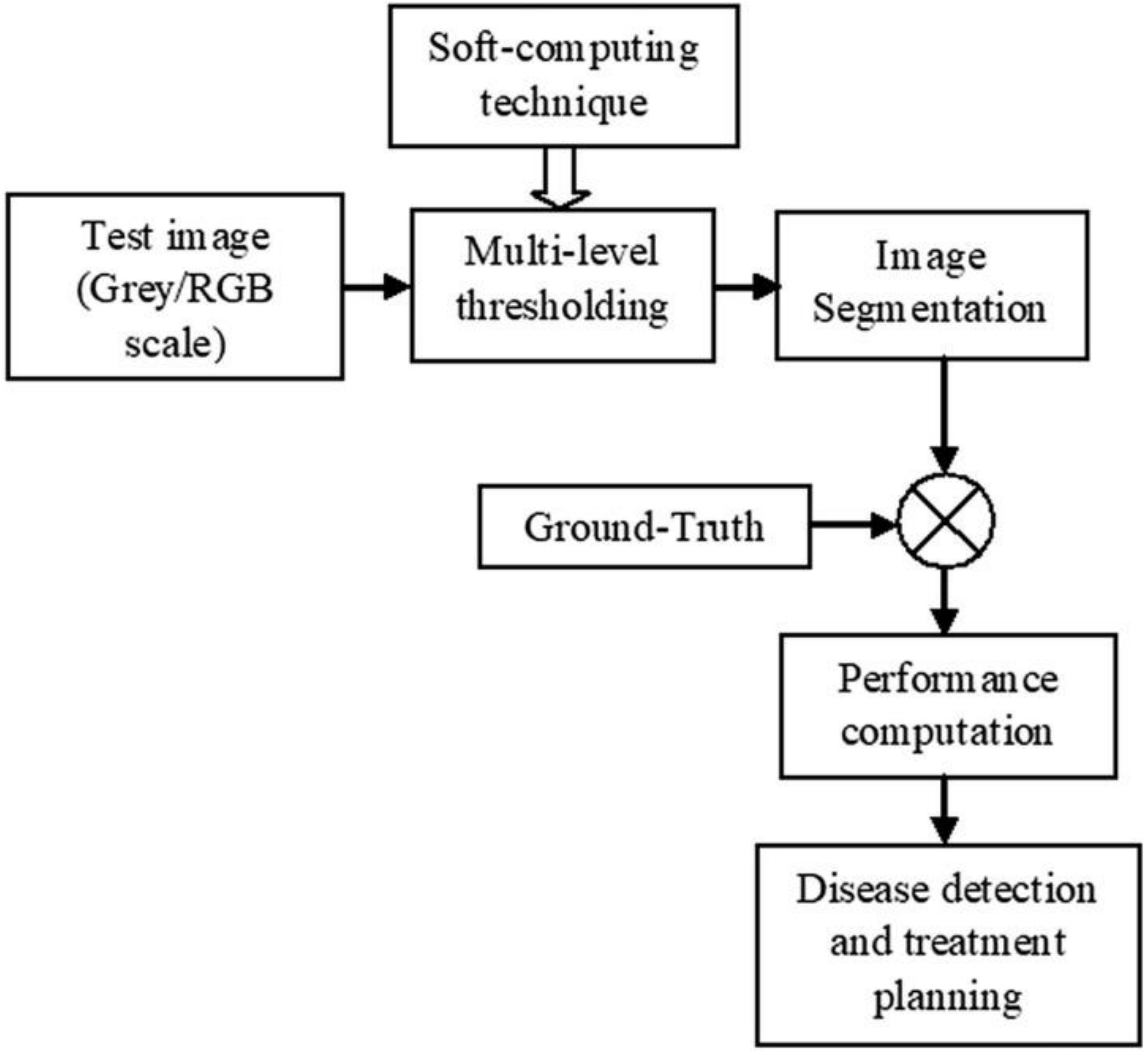


FIGURE 2.15 Structure of the Hybrid-Image Processing Methodology.

2.4.2 Need For Multi-level Thresholding

- Image thresholding based on a selected guiding function is extensively implemented in a variety of fields to pre-process the examination image. An image could be known as the arrangement of different pixels with reference to the thresholds. In a digital image, the pixel allotment plays a chief role and adjusting or grouping these pixels are preferred to enhance/change the information existing in the illustration.
- Bi-level thresholding is used to separate the raw picture into SOI and the background. In this process, the operator/computer algorithm is allowed to recognize a Finest-Threshold (FT) by means of a preferred function. Let the specified image have 256 thresholds (ranging from 0 to 255) and from this, one threshold value is selected as the Finest-Threshold as follows;

$$0 < FT < 255 \tag{2.3}$$

- In most applications, the information attained with the bi-level threshold is not appropriate. Hence, multi-thresholding is preferred to pre-process greyscale/RGB images.

2.4.3 Thresholding

- Image SOI enhancement based on the threshold value is extensively adopted in the literatures to practice a class of traditional and medical imagery. In most of the illustration assessment systems, thresholding is adopted as the pre-processing approach. In the thresholding procedure, the SOI in a chosen image (greyscale/RGB) is improved by grouping the pixels based on the selected optimal threshold value. The grouping of the image pixel will divide the SOI from the image background and other parts, and after this enhancement, the SOI can be extracted using a segmentation process.
- Figure 2.16 depicts the bi-level and multi-level threshold attained for a chosen test image with varied modalities. Figure 2.16 (a) and (b) presents the threshold results attained for a greyscale and RGB-scale image.

2.4.3 Thresholding

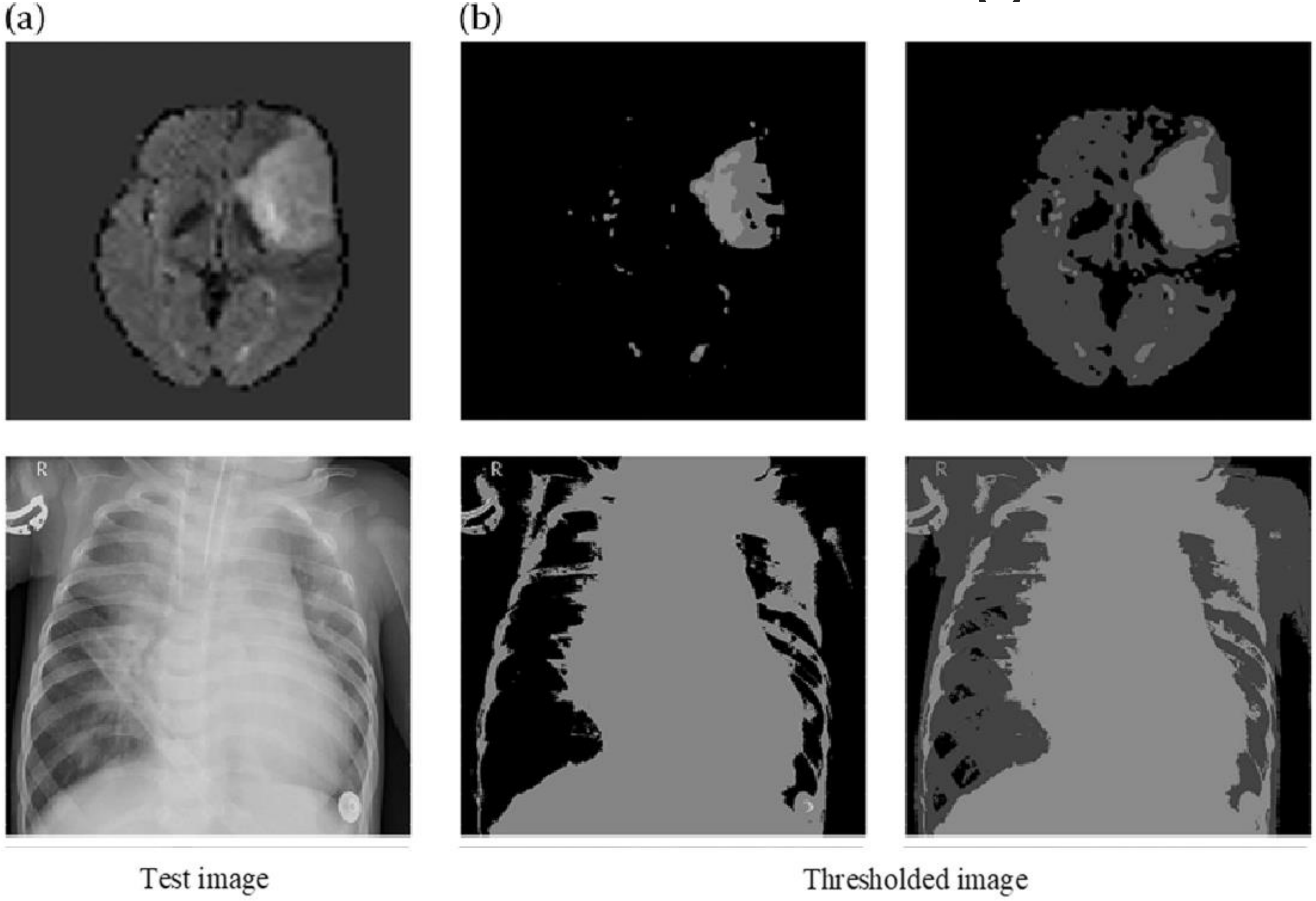


FIGURE 2.16 Multi-Level Threshold Implemented on Gray/RGB-Scale Image.

2.4.3 Thresholding

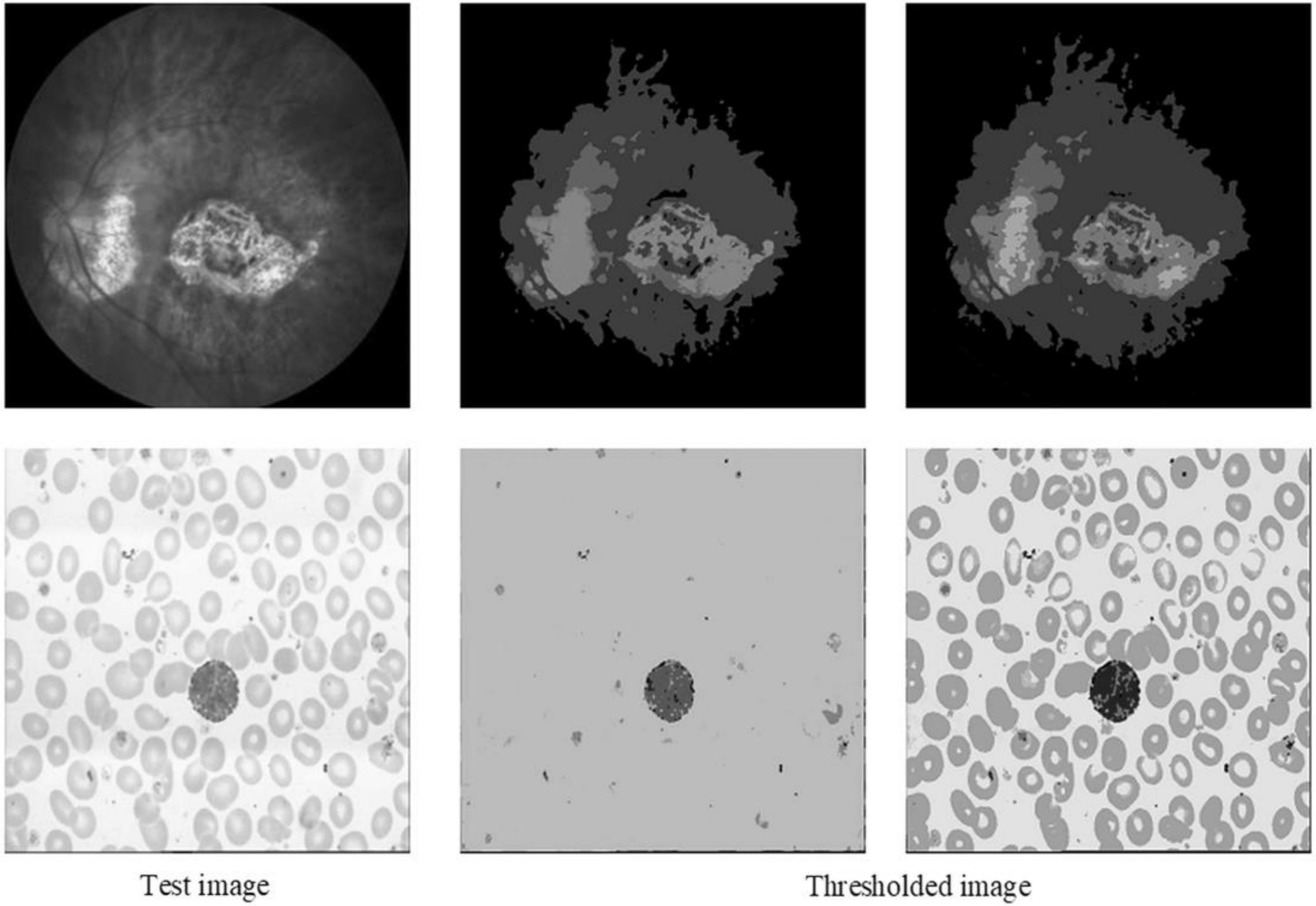


FIGURE 2.16 Multi-Level Threshold Implemented on Gray/RGB-Scale Image.

2.4.3 Thresholding

- The literature based confirms the availability of the thresholding procedure based on traditional and soft-computing driven techniques.
- In the traditional/operatorsupported technique, the optimum threshold recognition is done manually through trials. During this process, the threshold of the test image is rapidly varied with its histogram and different pixel grouping is studied to achieve the enhanced illustration. Identification of the optimum threshold through predictable process is complex and time-consuming.
- To overcome this difficulty, recently, threshold operation is performed under the supervision of soft-computing algorithms. In hybrid medical data evaluation techniques, thresholding is adopted as the pre-processing method to improve the SOI.

2.4.4 Implementation And Evaluation Of Thresholding Process

- Optimal threshold-based test image enhancement can be executed using manually or with a computer algorithm. The computation complexity in operator-assisted FT selection process needs more effort. Further, this complexity increases if the number of FT to be identified is >2 (i.e. multi-threshold selection). The operator adjusts the thresholds arbitrarily until the best image separation is achieved.
- Thus, in recent years, heuristic algorithm-assisted image thresholding has been widely proposed by researchers. In this method, a chosen heuristic-algorithm with a chosen objective function is implemented to enhance image information.

2.4.4 Implementation And Evaluation Of Thresholding Process

- After implementing thresholding using a chosen procedure, its outcome needs to be validated to verify the eminence of the proposed procedure. This validation can be achieved through a comparative analysis between the raw image and the threshold image.
- During this process, commonly considered image quality values such as root-mean-squared-error (RMSE), peak-signal-to-noise-ratio (PSNR, in dB), structural-similarity-index (SSIM), normalized-absolute-error (NAE), normalized-cross-correlation (NCC), average-difference (AD), and structural-content (SC) are computed for every image. Based on these values, the performance of the implemented thresholding technique is measured.

2.4.4 Implementation And Evaluation Of Thresholding Process

The commonly employed evaluation procedure to verify the result of the threshold process is depicted in Figure 2.17

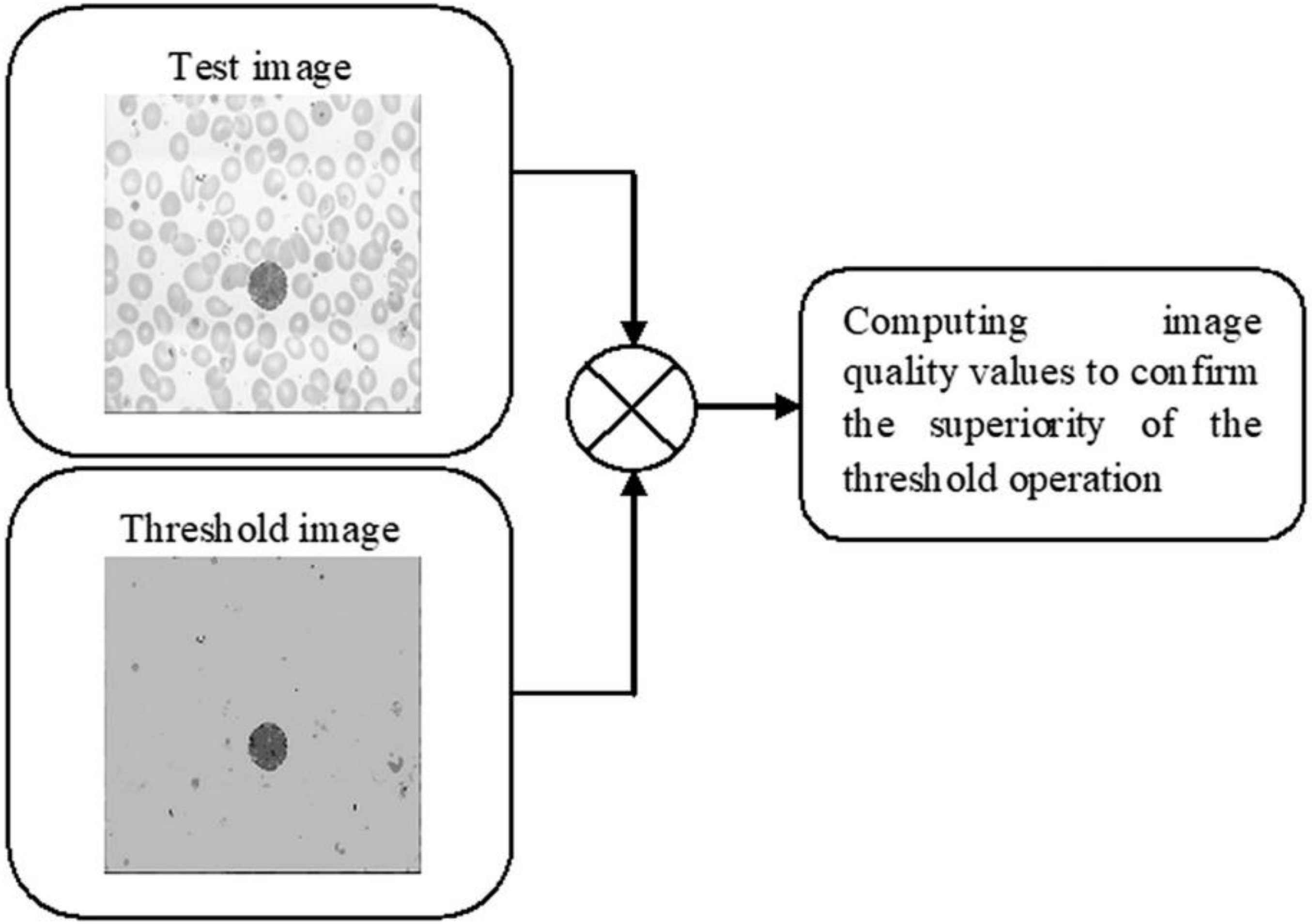


FIGURE 2.17 Performance Validation of the Thresholding Process.