Journal of Computer Science and Artificial Intelligence
ISSN: 3078-8242 (Print), ISSN: 3078-2309 (Online) | Vol. 8, No. 3, 2026

A Robust Sharpening Filter for Medical Images

Changkai Li [1, 2, *], Md Gapar Md Johar [3]

[1] College of Innovation and Entrepreneurship, Anhui Xinhua University, 230088, Hefei, China

[2] School of Graduate Studies, Management and Science University, Shah Alam 40100, Selangor, Malaysia

[3] Software Engineering and Digital Innovation Center, Management and Science University, Shah Alam 40100, Selangor, Malaysia

[*] **Corresponding author**: (Email: lichangkai@axhu.edu.cn)

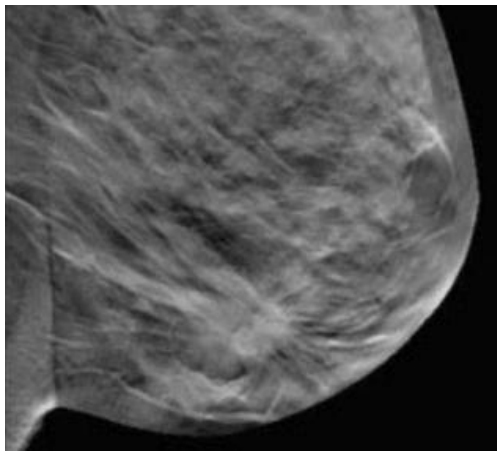
Abstract: To address the issue of image blurring caused by medical imaging mechanisms, a robust sharpening filter for improving the edges and fine details of medical images is proposed. The proposed sharpening process is achieved by subtracting specific spatial information, which is rapidly determined from the original image itself, and the amount of sharpness produced is controlled by an important adjustment weight. The above process helps to enhance the clarity of edges in the processed image and significantly improves the overall sharpness. Extensive experiments and comparisons conducted by applying the proposed sharpening filter to different medical images demonstrate that the proposed filter exhibits better robustness and is more suitable for medical image sharpening.

Keywords: Medical images, Robust, Sharpening filter.

1. Introduction

In digital images, contours, edges, local details, and textures are key features that contain important information and are crucial to visual quality. Image sharpening alters the apparent quality of an image without changing its content and can generally be defined as an improvement in clarity, which includes contour, edge information, textures, and important details that should have been clear in the image. . Image sharpening filters aim to enhance important image details while avoiding excessive artifacts [1]. Therefore, in the past few years, numerous medical image sharpening filter techniques have been proposed and applied in related applications [2]. Owing to the limitations of the imaging mechanisms of many practical and inevitable medical imaging devices, blurring of image details occurs during various medical imaging processes [3]. Among them, techniques based on Laplacian filtering [4], Non-local Mean with Local Statistics [5], and adaptive thresholding [6] are very classic. Medical images often have complex and novel texture structures, and the complexity of image sharpening techniques is growing; however, with the rapid development of modern imaging technology, various real-world applications require low-complexity techniques [7]. To overcome the above limitations, this paper proposes a low-complexity, simple, and efficient robust sharpening filter for enhancing image detail structures. The sharpening process of the proposed filter is achieved by subtracting specific spatial information from the source image, which is rapidly determined from the source image itself. At the same time, a special adjustment weight is designed to control the amount of sharpness produced. Experimental observations show that when the proposed image sharpening filter design is applied to medical images, it helps to reduce noise amplification, increase edge clarity, and exhibits significant effects in enhancing image details in the sharpened images.

To validate the technique in this study, various real degraded 3D mammograms (as shown in Figure 1), computed tomography (CT), and magnetic resonance (MR) images were collected from different open-access databases on the Internet and used for experimental and comparison purposes. The main reason for using only real degraded images is to understand, in a realistic manner, the actual processing capability of the proposed filter in solving the problem. Therefore, despite its simple structure, the proposed filter shows great promise in recovering results of acceptable quality from degraded observations.



(a)Before Sharpening

(b) After Sharpening

Figure 1. Proposed Sharpening method

2. Related Work

In this section, a number of representative existing medical image sharpening techniques are first briefly introduced. [8] proposed an aerial photograph enhancement system that embeds a bilateral filter into the unsharp masking (UM) framework. The core idea is to replace the Gaussian low-pass filtering in traditional UM with edge-preserving bilateral filtering, thereby enhancing contrast while denoising, with a particular focus on mixed noise problems in remote sensing/aerial images. [9] proposed a medical image fusion method based on the nonsubsampled shearlet transform. The core strategy is to adopt an average fusion rule for low-frequency subbands and a local Laplacian energy fusion rule for high-frequency subbands, so as to preserve anatomical structures while incorporating functional information. [10] proposed a novel variant of UM based on maximum local variation (MLV), namely MLVUM. The core innovation lies in replacing the fixed Gaussian kernel in traditional UM with an adaptive Gaussian smoothing filter controlled by maximum local variation, combined with an MLV weighting mechanism, thereby achieving selective sharpening of MR image edges while avoiding noise amplification and overshoot artifacts. [11] proposed a new technique using nonlinear polynomial filters to improve the sharpness of lesion edges in mammograms. This technique improves sharpness in a manner that reduces dependence on preset thresholds. To this end, a modified logarithmic image processing model relying on the characteristics of the human visual system is used to process images and produce results of acceptable quality. In addition, [12] proposed a new MRI sharpening technique based on wavelet fusion and multiscale analysis. This technique denoises the input image by using a two-dimensional dual-tree-based method in the wavelet domain. Thereafter, the resulting image is passed through a set of five sharpening methods, and the final output is obtained using a unique image fusion technique. Furthermore, [13] proposed a new technique for sharpening low-dose X-ray fluoroscopic images. This technique enhances sharpness and avoids overshoot effects by combining a region-adaptive high-pass filter with a unique transient enhancement method. Subsequently, a newly developed artifact and noise reduction filter utilizing edge-direction kernels is applied to remove noise and artifacts from the obtained results. [14] developed a new sharpening technique for MR images based on singular value decomposition (SVD) and Laplacian pyramid, which incorporates the shape-invariant features of LP into the SVD technique to produce the final results. As can be seen from the reviewed techniques, their complexities vary due to the use of different processing concepts. Moreover, they all share the same concept of providing sharp results while avoiding the generation of artifacts. Therefore, it can be said that there is a great need to develop a new sharpening technique that utilizes simple concepts and can quickly produce high-quality results.

3. The Proposed Sharpening Filter

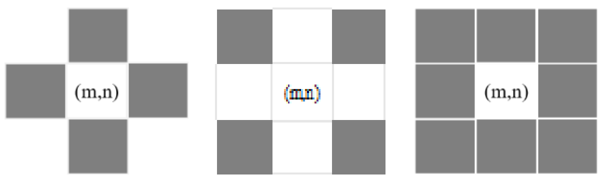
Among the medical image sharpening filter techniques proposed in recent years, the Nimble Filter is an image sharpening filter with an extremely simple structure and very fast computational speed [15]. The core idea is to use the horizontal/vertical displacement information of the image itself to generate sharpening effects, requiring only a single adjustable weight parameter, and demonstrating superior performance over several classical methods on both 2D and 3D medical images (mammograms, CT, MRI). the Nimble Filter computes a blurred version of the input image and then subtracts it from the input image itself using an adjustment weight in a certain manner. In detail, the Nimble filter operates by finding the average of the horizontal and vertical displacements of the input image and then multiplying the determined average by a special weighting parameter. This Nimble Filter allows the generation of a blurred version of the input image that contains spatial information highly beneficial to the sharpening process. By applying this process, not only are structural edges preserved, but the clarity of these edges is also enhanced, resulting in images with more visible details. In [15], within a 4-neighborhood pixel framework, this nimble filter operates by subtracting the spatial information of the four neighboring pixels from the central pixel, as illustrated in Figure.3(a). Subsequently, a weight coefficient is designed to control the degree of sharpening. The specific calculation operator is:

$$y(m,n) = k*V(m,n)+(1-k)*(V(m,n+1)+V(m,n-1) +V(m+1,n)+V(m-1,n))/4 \tag{1}$$

Here, k represents the weight coefficient controlling the sharpening intensity. Furthermore, $(V(m,n+1)+V(m,n-1)+V(m+1,n)+V(m-1,n))/4$ refers to the mean value of the four neighboring pixels (vertical and horizontal) surrounding the central pixel $V(m,n)$. We simplify the notation for this mean value as $\overline{V_4}(m,n)$, allowing Equation (1) to be transformed into :

$$y(m,n)=\overline{V_4}(m,n)+k*[V(m,n)-\overline{V_4}(m,n)] \tag{2}$$

By examining Equation (2), it can be understood that this method essentially inherits the core idea of classical unsharp masking. It achieves the sharpening effect by adding the difference between the source image and the mean image calculated based on the 4-neighborhood (which functions as a smoothed image) back onto the 4-pixels neighborhood mean image. This method employs the difference operation between the central pixel and its four neighboring pixels. This effectively achieves sharpening of image object edges by detecting edge variations in the horizontal and vertical directions, respectively. However, this method fails to account for edge variations in the two diagonal directions, as shown in Figure 2(b). For images with more complex textures, its sharpening effect is relatively inferior, as shown in Figure 2(a).



(a) 4-pixels (b) Diagonal (c) 8 -pixels

Figure 2. Sharening mask

Consequently, this study proposes an sharpness improvement method based on an 8-pixels neighborhood configuration, as depicted in Figure 2(c). This approach not only effectively detects edges in the horizontal and vertical directions but also captures edge variations along the two diagonal directions, thereby achieving a more pronounced and comprehensive sharpening effect. This facilitates the enhancement of finer image details, rendering it particularly suitable for images with complex textures where improving local contrast is essential. The proposed 8-pixels neighborhood-based sharpening filter, denoted as $V_8(m,n)$, is formulated as follows:

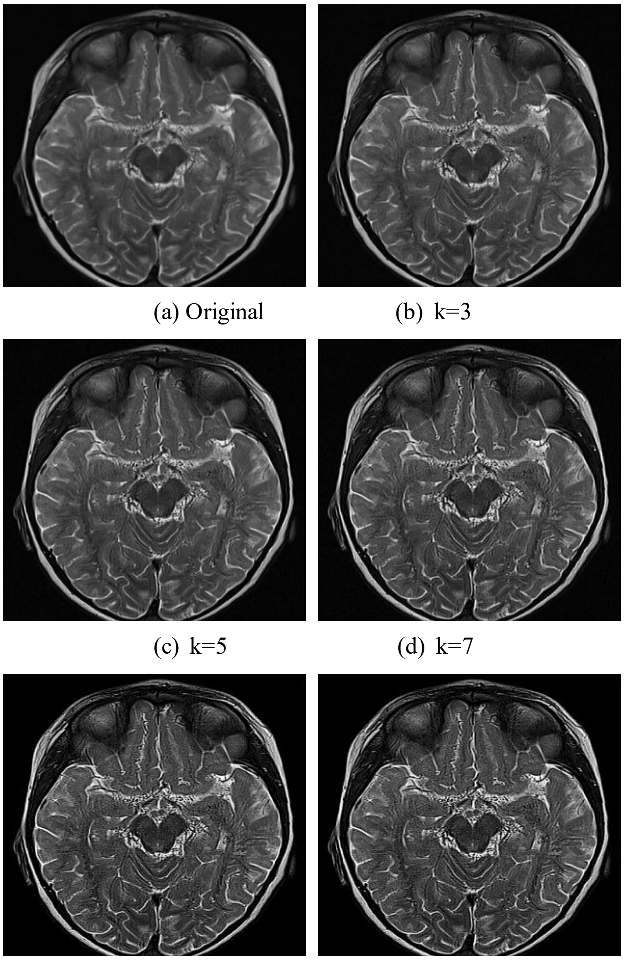
$$V_8(m,n)=\overline{V_8}(m,n)+k*[V(m,n)-\overline{V_8}(m,n)] \quad (3)$$

Where $\overline{V_8}(m,n)$ represents the mean intensity value of the 8- pixels neighboring pixels surrounding the central pixel V(m,n), as shown in the following Equation:

$$\overline{V_8}(m,n) = (V(m-1,n-1)+V(m-1,n)+V(m-1,n+1)+V(m,n-1) +V(m,n+1)+V(m+1,n-1)+V(m+1,n)+V(m+1,n+1))/8 \quad (4)$$

4. Results and Discussion

To verify the performance of the proposed robust sharpening filter for medical image detail enhancement, it was compared with several well-known sharpening techniques, including the Laplacian kernel neighborhood 4 operator [4], the Nimble Filter [15], and MLVUM [10]. It is worth mentioning that all experiments and comparisons were conducted using MATLAB 2022 on a 2.8 GHz Core I7 processor with 16 GB of memory. Figures 3 and 4 show the medical image enhancement results after processing with the proposed sharpening filter under different values of the adjustment weight factor k.



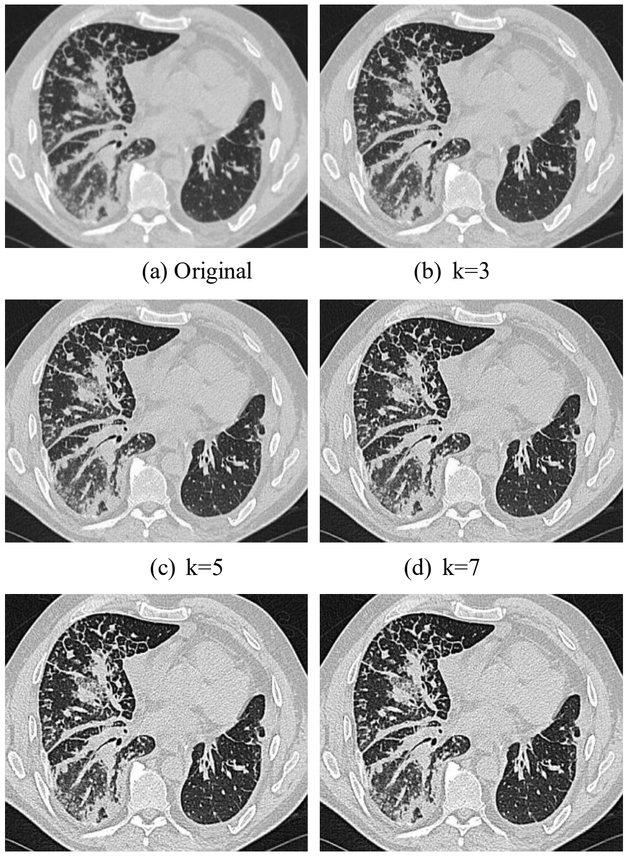
(a) Original (b) k=3

(c) k=5 (d) k=7

(e) k=9 (f) k=11

Figure 3. Processing results of real medical CT images using the proposed sharpening filter

The validation process was divided into two stages. In the first stage, the main focus was on verifying the effect of the new image sharpening filter on image sharpening results when different values of k are used in the proposed sharpening filter. As shown in Figures 3 and 4, it can be observed that as the k value increases, the sharpening effect quality of the image improves significantly; however, if the k value is too large, artifacts may still occur. Therefore, in practical applications, a reasonable k value should be selected so that image sharpening can be achieved while avoiding excessive sharpening.



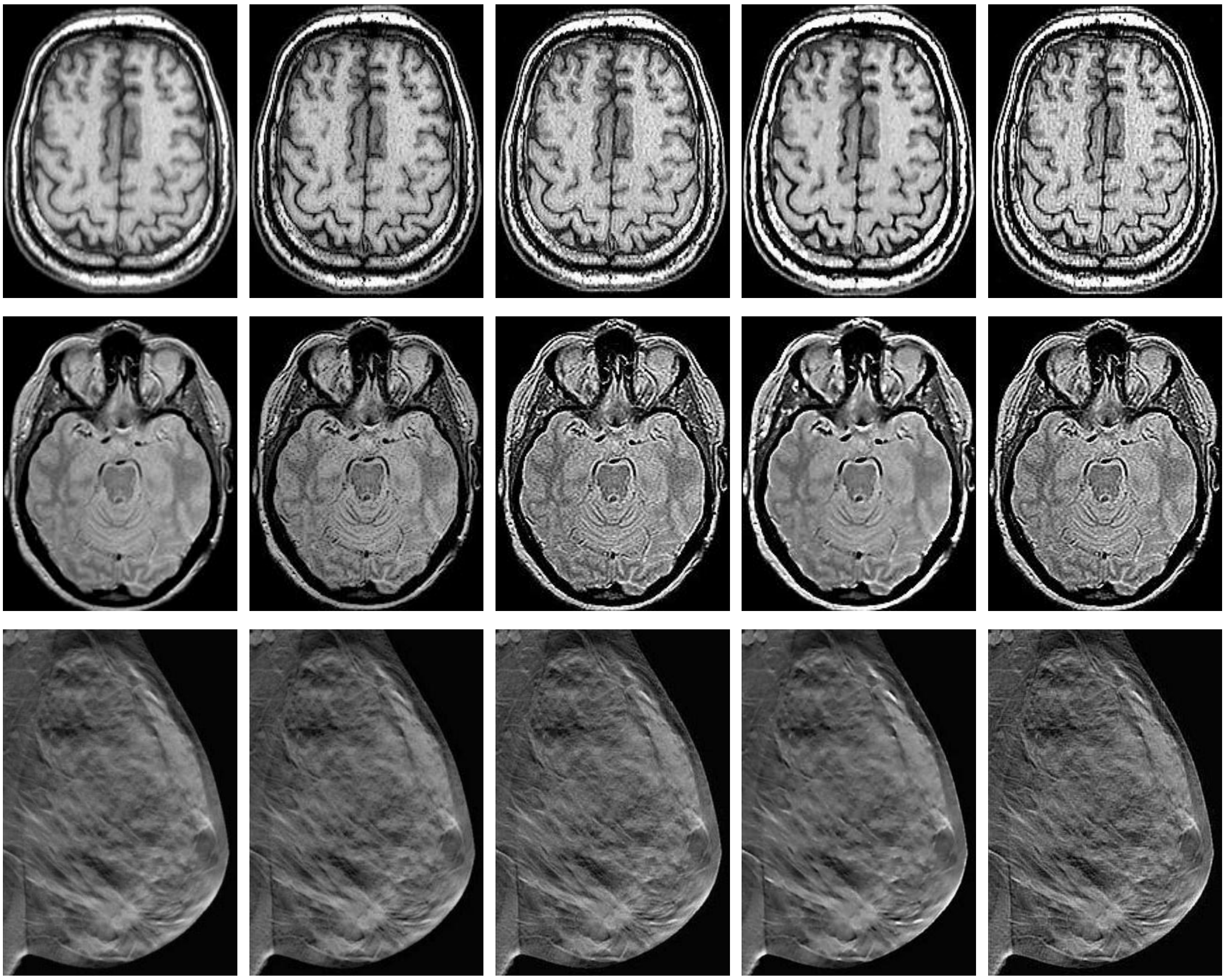
(a) Original (b) k=3

(c) k=5 (d) k=7

(e) k=9 (f) k=11

Figure 4. Processing results of real medical MR images using the proposed sharpening filter

In the second stage of validation, the proposed sharpening filter was compared with the classical methods [4, 15, 10]. Observing the medical image sharpening results shown in Figure 5, the first column represents the source images, and columns 2–5 represent the sharpening results of the methods [4, 15, 10], and the proposed method, respectively. Each row represents the sharpening results of different sharpening methods on the same source image. From the sharpening experimental results, it can be seen that the sharpening effect of [4] is not obvious, [15] achieves relatively good sharpening results, and [10] achieves the best noise suppression effect among the compared methods, but at the same time, this does indeed affect its sharpening performance. Overall, in this experiment, the proposed sharpening filter (k = 5) achieves the best performance in terms of visual quality and image details, and outperforms the other compared techniques.



(a) Original (b) Laplace [4] (c) Nimble Filter [15] (d) MLVUM [10] (e)Proposed

Figure 5. Sharpening results of real medical images of different modalities.

In fact, each of the compared techniques has certain performance limitations. Therefore, the proposed sharpening filter produces better results than the compared techniques because of its simple structure, which utilizes only a small amount of computation, thereby enabling fast implementation. Likewise, it avoids excessively amplifying potential image noise, introduces no undesirable artifacts, and does not cause over-sharpening, thus providing acceptable sharpness and a natural appearance for the processed images. Nevertheless, the proposed sharpening filter controls the degree of sharpness through the use of the weight factor k, with image sharpness increasing as the k value increases, and vice versa. Overall, the proposed filter has advantages, but it has one drawback, namely that the k value must be determined empirically.

5. Conclusion

In this study, a robust sharpening filter for medical images is proposed, which improves image sharpness by utilizing specific 8-neighborhood spatial image information and a unique sharpening adjustment weight. Accordingly, real degraded images from three medical modalities were used to verify the efficiency of the proposed filter. Based on the obtained results, the proposed filter shows advantages over other extensively studied related techniques in terms of visual effects and image details. It produces naturally appearing results without the over-sharpening effects and unnatural appearance produced by the compared techniques.

Acknowledgements

The authors gratefully acknowledge the financial support from Key Nature Science Research Project Foundation of Anhui Provincial Department of Education (2025AHGXZK30905) and Key Nature Science Research Project Foundation of Anhui Xinhua University (2025zrzdi13).

References

[1] Haq, N., Hayat, K., Noreen, N., & Puech, W. (2011). Image sharpening by DWT-based hysteresis. In International conference on advanced concepts for intelligent vision systems (pp. 429–436). https://doi.org/10.1007/978-3-642-23687-7_39

[2] Singh, N. K., & Sunaniya, A. K. (2016). An adaptive image sharpening scheme based on local intensity variations. Signal, Image and Video Processing, 10(7), 1303–1310. https://doi.org/10.1007/s11760-016-0987-1

[3] Simi, V. R., Edla, D. R., & Joseph, J. (2023). An inverse mathematical technique for improving the sharpness of magnetic resonance images. Journal of Ambient Intelligence and Humanized Computing, 14, 2061–2075. https://doi.org/10.1007/s12652-021-03416-1

[4] Yang, C. C. (2014). Finest image sharpening by use of the modified mask filter dealing with highest spatial frequencies. Optik-International Journal for Light and Electron Optics, 125(8), 1942–1944. https://doi.org/10.1016/j.ijleo.2013.09.070

[5] Yang, J., Fan, J., Ai, D., Wang, X., Tang, S., & Wang, Y. (2017). Local statistics and non-local mean filter for speckle noise reduction in medical ultrasound image. Signal, Image and Video Processing, 11(3), 501–508. https://doi.org/10.1007/s11760-016-0987-1

[6] Joseph, J., Anoop, B. N., & Williams, J. (2019). A modified unsharp masking with adaptive threshold and objectively defined amount based on saturation constraints. Signal, Image and Video Processing, 13(2), 301–308. https://doi.org/10.1007/s11760-018-1361-2

[7] Ma, T., Li, L., Ji, S., Wang, X., Tian, Y., Al-Dhelaan, A., et al. (2014). Optimized Laplacian image sharpening algorithm based on graphic processing unit. Physica A: Statistical Mechanics and its Applications, 416, 400–410. https://doi.org/10.1016/j.physa.2014.09.026

[8] Regan, D., & Padmavathi, C. (2019). An unsharp masking algorithm embedded with bilateral filter system for enhancement of aerial photographs. International Journal of Recent Technology and Engineering (IJRTE), 8(2), 1234–1240. https://doi.org/10.35940/ijrte.B1234.078219

[9] Alam, N., Mehto, A. K., Haq, Z. A., & Mehdi, S. A. (2022). Medical image fusion in NSST domain utilizing Laplacian low energy and average fusion rule. In Proceedings of the 2022 International Conference on Computing, Communication, and Intelligent Systems (ICCCIS) (pp. 123–128). IEEE.

[10] Edla, D. R., Simi, V. R., & Joseph, J. (2022). A noise-robust and overshoot-free alternative to unsharp masking for enhancing the acuity of MR images. Journal of Digital Imaging, 35(4), 1013–1031. https://doi.org/10.1007/s10278-022-00620-x

[11] Bhateja, V., Misra, M., & Urooj, S. (2016). Non-linear polynomial filters for edge enhancement of mammogram lesions. Computer Methods and Programs in Biomedicine, 129, 125–134. https://doi.org/10.1016/j.cmpb.2016.01.007

[12] Zafeiridis, P., Papamarkos, N., Goumas, S., & Seimenis, I. (2016). A new sharpening technique for medical images using wavelets and image fusion. Journal of Engineering Science & Technology Review, 9(3), 187–200.

[13] Lee, M. S., Park, C. H., & Kang, M. G. (2017). Edge enhancement algorithm for low-dose X-ray fluoroscopic imaging. Computer Methods and Programs in Biomedicine, 152, 45–52. https://doi.org/10.1016/j.cmpb.2017.09.010

[14] Jeevakala, S. (2018). Sharpening enhancement technique for MR images to enhance the segmentation. Biomedical Signal Processing and Control, 41, 21–30. https://doi.org/10.1016/j.bspc.2017.11.007

[15] Al-Ameen, Z. (2018). Sharpness improvement for medical images using a new nimble filter. 3D Research, 9(1), 12. https://doi.org/10.1007/s13319-018-0168-3