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The Importance of Dithering Technique Revisited With Biomedical Images–A Survey

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ABSTRACT Dithering is used regularly for printing monochrome images. Newspaper photographs are dithered for example. In the monochrome images, each pixel is stored as a single bit. The smallest unit of the digital image is a pixel, i.e., the picture element. The bits-per-pixel is the significant metric to the appearance level of the nature of the image. To obtain the diverse gray shades, different patterns of white and black dots are used. This paper deals with the underlying fundamental behind the dithering with medical test images. The techniques such as quantization, dithered, dithered and quantized, dithered and quantized with subtraction, and the adoption of filtering kernel are implemented. The performance of each one is evaluated with mean-square-error and peak signal-to-noise ratio metrics. Three medical test images such as one mammogram image, one angiogram image, and one thermal image are used in this paper. The Matlab R2018a tool is used to obtain the simulation results.

INDEX TERMS Dithering, filtering, half-toning, MSE, PSNR.

I. INTRODUCTION

The principles of DSP are essential in day-to-day life with devices such as mobile phones, digital cameras, disk drives, digital televisions, automobiles, and digital audio players. Digital signal processing (DSP) is a thrust and core subject in many electrical and computer engineering curricula. Many technical approaches in DSP are easier to understand, even though being mathematically troublesome. At present, DSP brings techniques, innovations, and algorithms to solve various practical problems in engineering, scientific, and multimedia fields. The DSP filed has frequently developed its strength from the interplay theoretical concepts, and real-time applications [1], [2]. The uses of DSP are illustrated in Figure 1.

This study focuses mainly on image dithering. Dithering or half-toning is a method which is used to produce a grayscale image on a computer monitor, printer or other bi-level displays. Dithering means that the unwanted bands can be expelled removed by introducing noise along the edges. For the superior results, the better quality noises are added such as Gaussian noise in which the random samples follow the normal distribution. That is in general, the structural errors from the image are replaced with the noise with preserving the most information. Mainly, the dithering or half-toning are popular methods for obtaining grayscale images in books, magazines, and newspapers.

Dithering is usually used in displaying two-tone, i.e., monochrome images [3], [4]. During the image quantization, the discontinuities in the image intensities would look like contours. For example, in one-dimensional, the false contour may look like as illustrated in Figure 2. Similarly, the false-contouring would appear in two-dimensional images as shown in Figure 3.

Human eyes are more sensitive to contours. The false contouring effects can be nullified using the dithering technique. In common, we disintegrate the contouring effect by adding random noise. During the quantization, the quantization noise itself uniformly distributed in the whole image. Nonetheless, by adding additional noise to the quantized image, further the contouring effect can be minimized and hence resulting in the poor mean-square-error (MSE). By incorporating appropriate low-pass filter (smoothing) on the quantized and dithered image, the noise can be reduced and hence resulting in the improvement in MSE. By using the dithering technique,

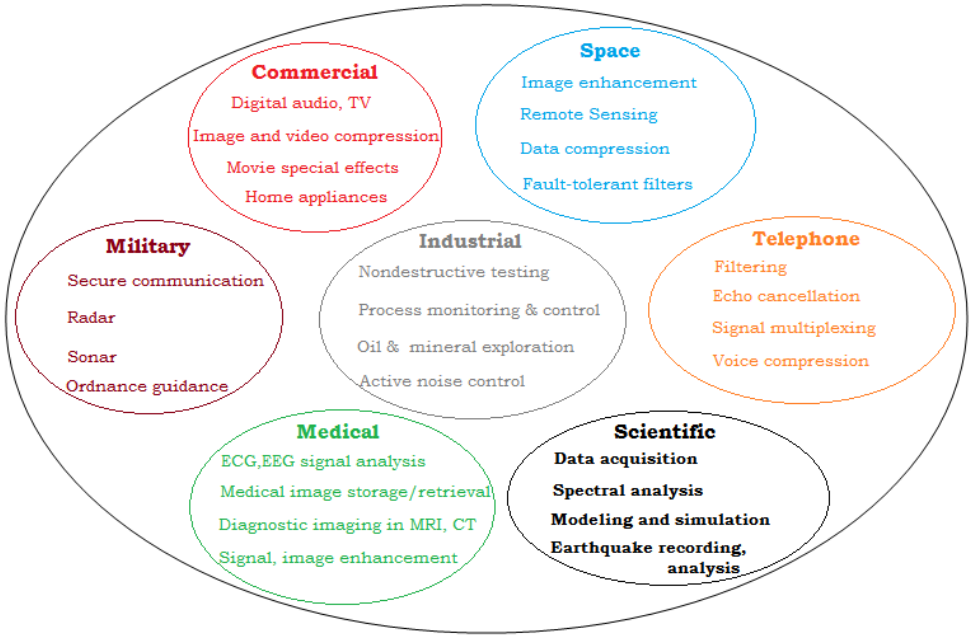

FIGURE 1. Applications of DSP.

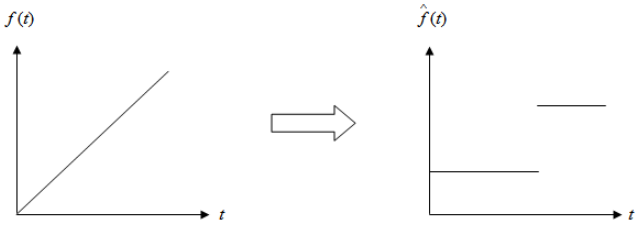

FIGURE 2. Contouring in 1-D signal.

more details can be seen in the result rather than from the quantized or quantized and filtered [5], [6].

With slight modifications in the algorithm or technique, the color dithering can be achieved in which each color channel should be treated independently. Dithering technique can be used often for artistic reasons too; it can be used or web design to reduce the file size of the image with lower color counts and hence to result in better bandwidth utility without compromising the quality of the image. The dithering related techniques and applications are shown in Figure 4.

II. MATERIALS AND METHODS

The dithering techniques are detailed in this Section. The information about the test images and the corresponding results and discussion are described in Section 3. Finally, the conclusions are obtained in Section 4.

A. DITHER

Dithering techniques are often used in signal processing and control systems to mitigate the effects of hysteresis, nonlinearity, static friction, quantization, gear backlash, etc. In most circumstances, dither inputs have been used to enhance the system performance. In general, to convert the grayscale image to black-and-white, threshold technique is applied. Suppose, if the noise is added to a grayscale image before

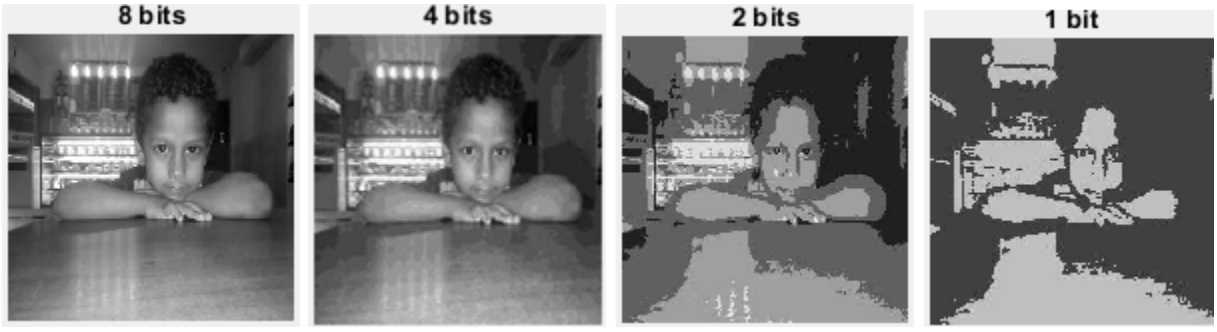

FIGURE 3. Contouring with uniform quantization.

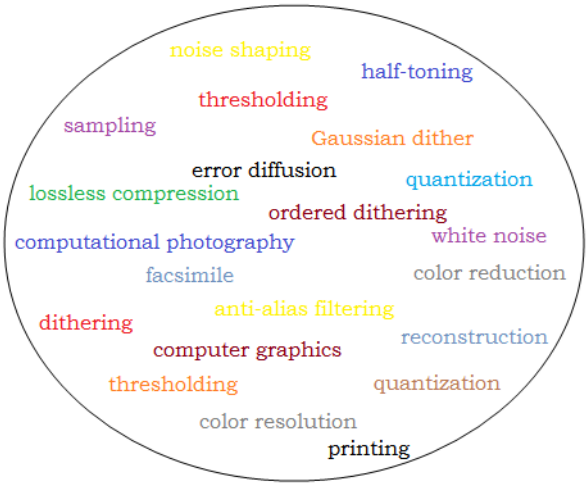

FIGURE 4. Dithering related techniques and applications.

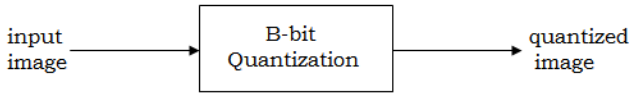

FIGURE 5. The quantized image.

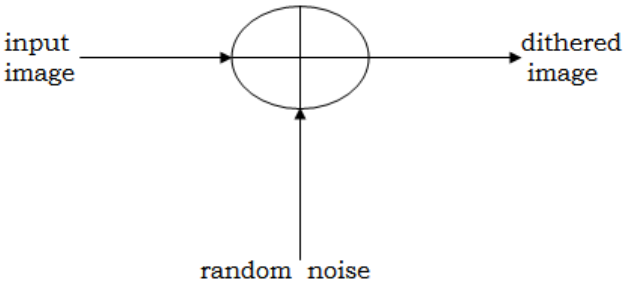

FIGURE 6. The dithered image.

using the threshold then the resulting image will look like a more natural black and white image [5], [7]. Dithering technique exploits spatial integration in our eye by distributing errors among pixels. Also with the aid of dithering, the higher range of perceptible intensities can be displayed with reduced quantization effects and hence with more resolution. Due to the quantization, the visual artifacts will be reduced.

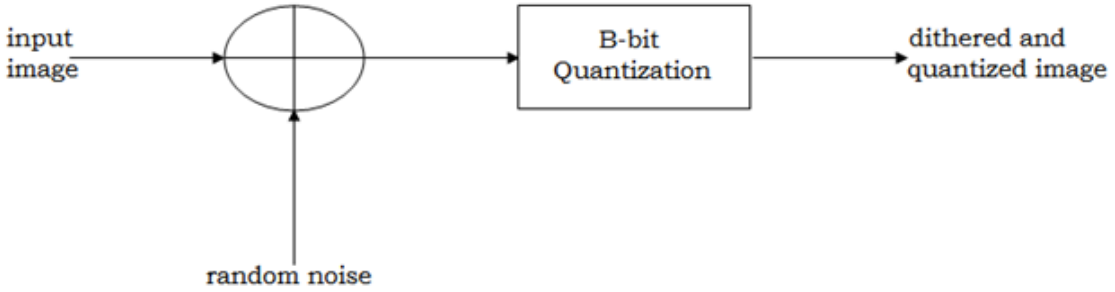

FIGURE 7. The dithered and quantized image.

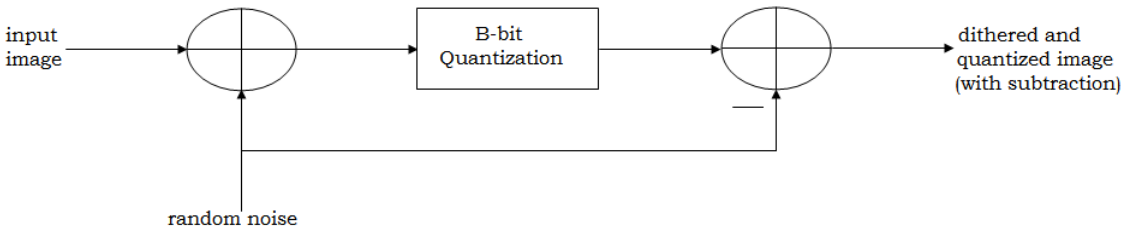

FIGURE 8. The dithered and quantized image with subtraction [13].

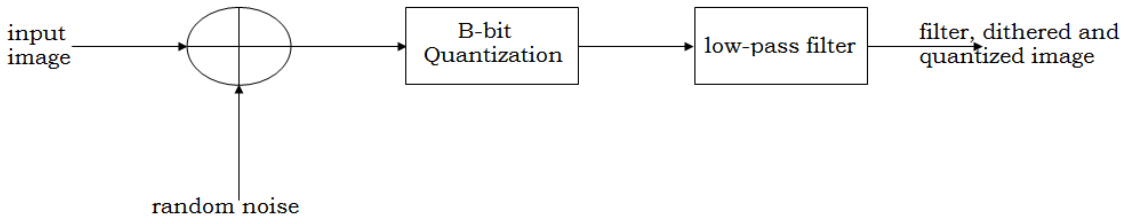

FIGURE 9. The low-pass filtered, dithered and quantized image [5].

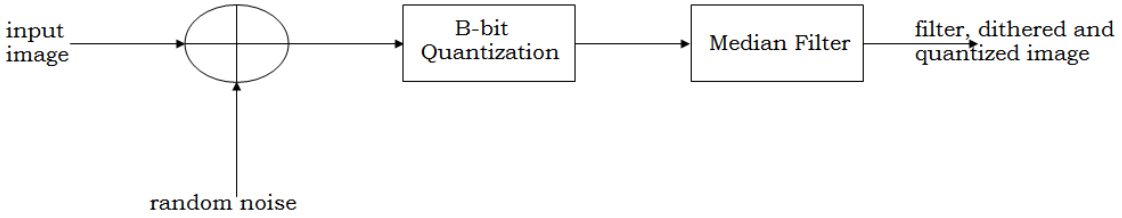

FIGURE 10. The median filtered, dithered and quantized image.

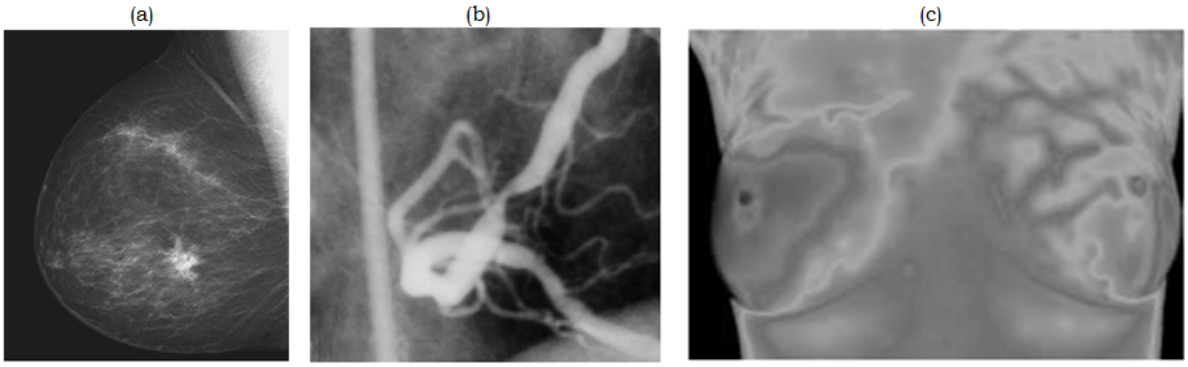

FIGURE 11. (a) mammo.tif; (b) angiogram.tif; (c) thermography.tif.

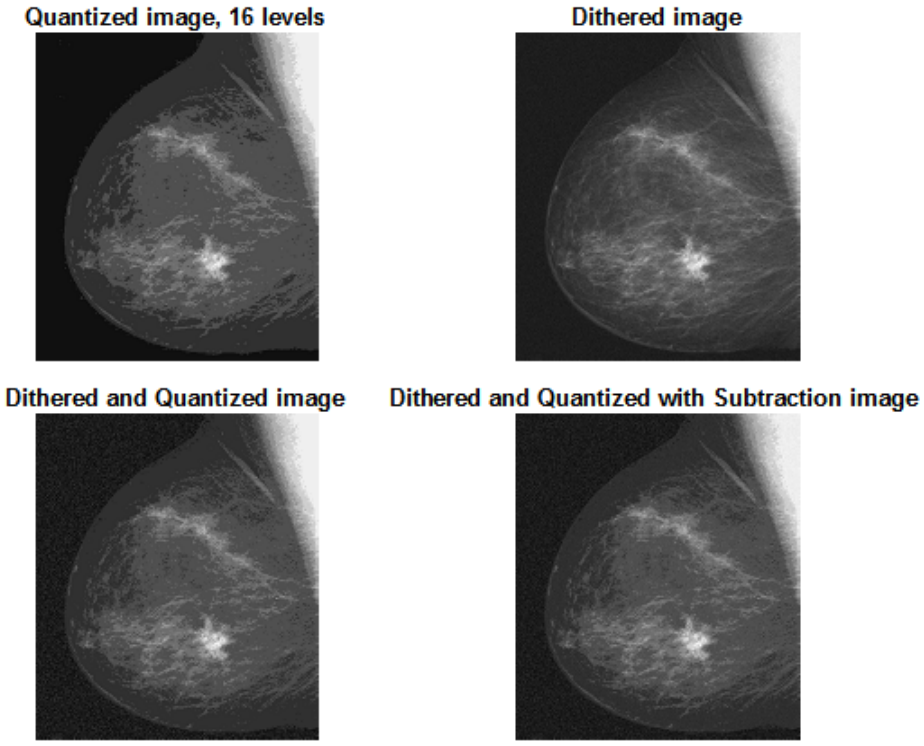

FIGURE 12. Quantized, dithered, dithered and quantized, and dithered and quantized with subtraction images.

Also with sampling and reconstruction, the visual artifacts can be too reduced. Since the frame buffers have limited number of bits per pixel, the visual artifacts would appear. Also, these visual artifacts will arise due to the limited intensity resolution, that is, physical devices may have limited dynamic range [8]–[12].

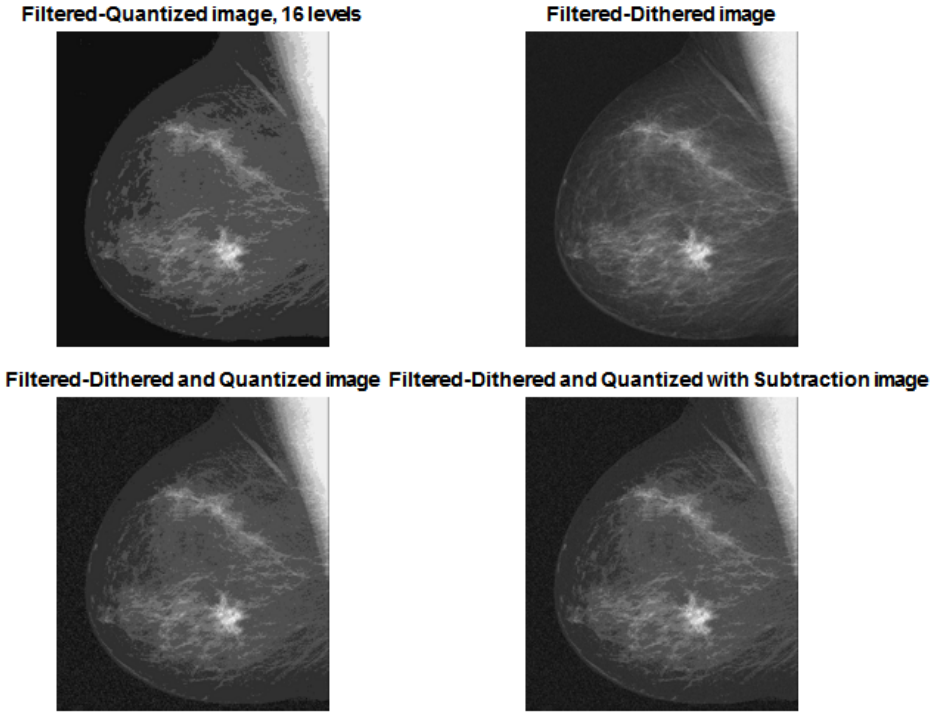

FIGURE 13. 2D low-pass filtered images.

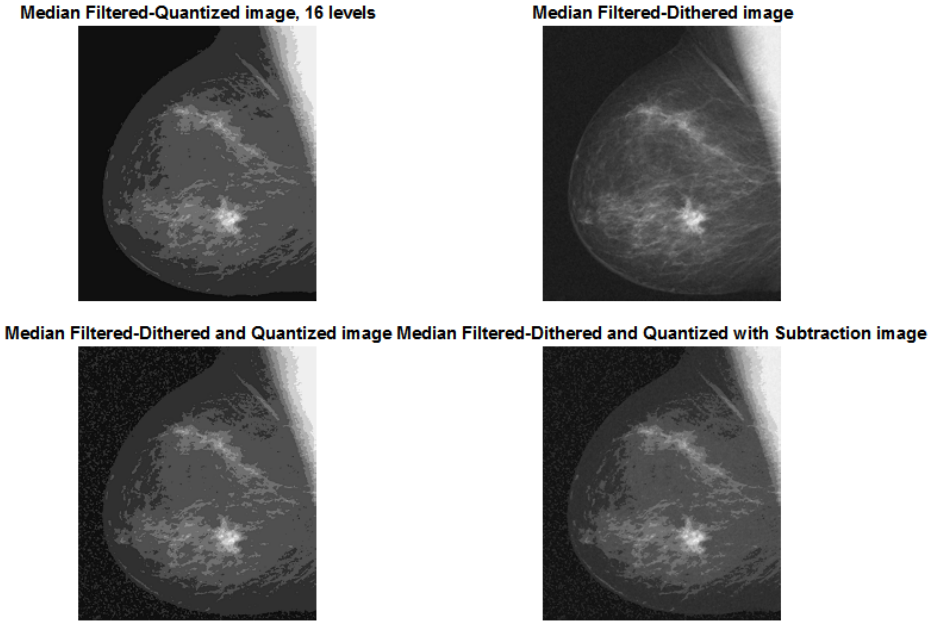

FIGURE 14. 2D median filtered images.

B. DITHERING TECHNIQUES

The dithering techniques used in this study are described as follows:

- The quantization
- The dithering
- The dithering and quantization
- The dithering and quantization with subtraction [13]
- In the end, filtering by the 2-D low pass filter kernel [1 2 1; 2 4 2; 1 2 1] [5]:
  - Filter the quantized image
  - Filter the dithered image
  - Filter the dithered and quantized image

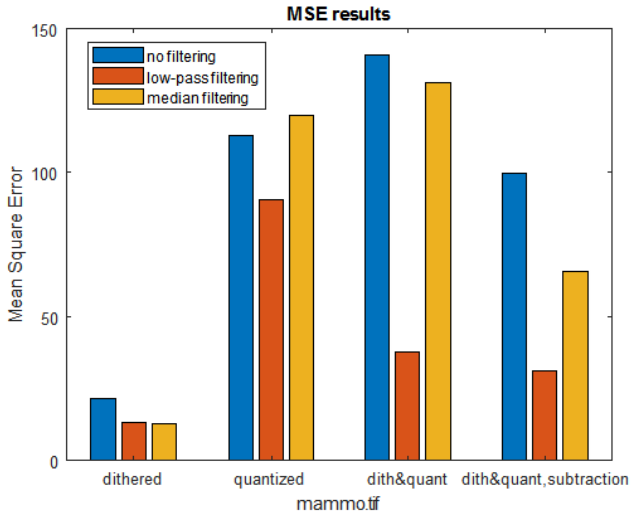

FIGURE 15. MSE results of the "mammo.tif" image.

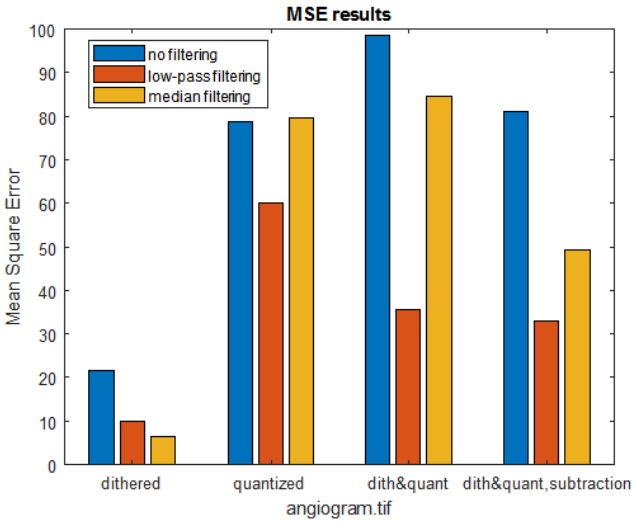

FIGURE 17. MSR results of the "angiogram.tif" image.

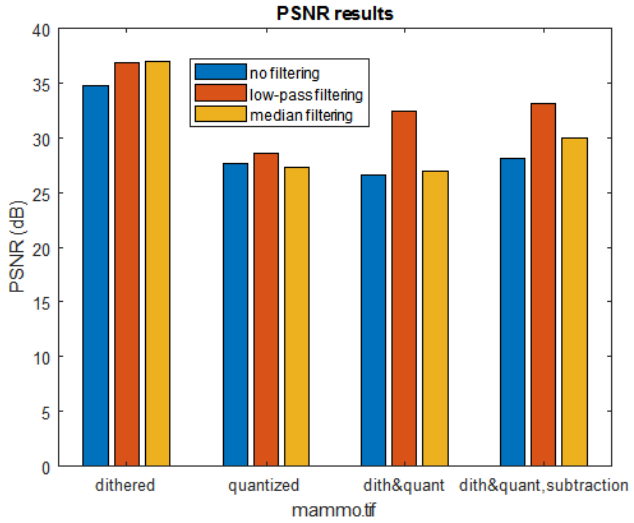

FIGURE 16. PSNR results of the "mammo.tif" image.

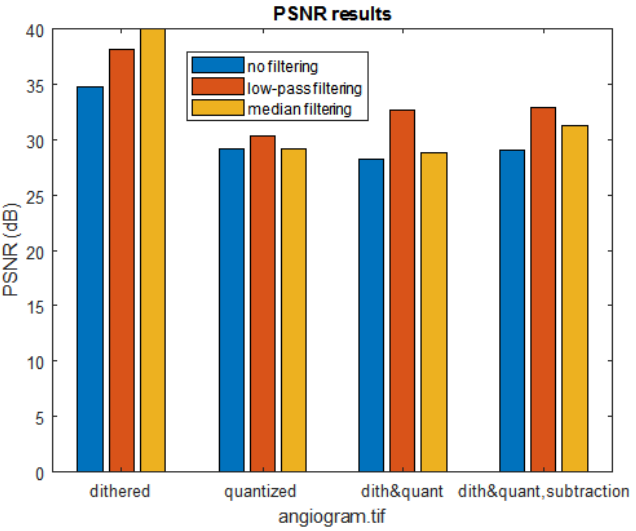

FIGURE 18. PSNR results of the "angiogram.tif" image.

- Filter the dithered and quantized with subtraction image
- In the end, median filtering with [3 × 3] size:
- Median filter the quantized image
- Median filter the dithered image
- Median filter the dithered and quantized image
- Median filter the dithered and quantized with subtraction image

The quantization, dithering, dithering and quantization, the dithering and quantization with subtraction, the low-pass filtered the dithering and quantization methods, and the median filtered the dithering and quantization methods are shown in Figures 5, 6, 7, 8, 9, and 10 respectively.

III. RESULTS AND DISCUSSION

In this section, the test medical test images, the processed images, results, and discussion are detailed.

A. TEST IMAGES

In this study, three medical test grayscale images, namely "mammo.tif", "angiogram.tif", and "thermography.tif" with sizes 512 × 444, 470 × 495, and 148 × 223 respectively are used [14]. Figure 11 shows the medical test images which are scaled up or down for the sake of uniformity in this page.

B. PROCESSED IMAGES

The quantized, dithered, dithered and quantized, and dithered and quantized with subtraction images (mammo.tif) are shown in Figure 12. Figure 13 shows the same results with a 2D low-pass filter at the end. Figure 14 shows the similar results with a 2D median filter at the end.

C. MSE AND PSNR RESULTS

The simulation results reveal that the methods, for the dithering method, the median filtering with the dithered,

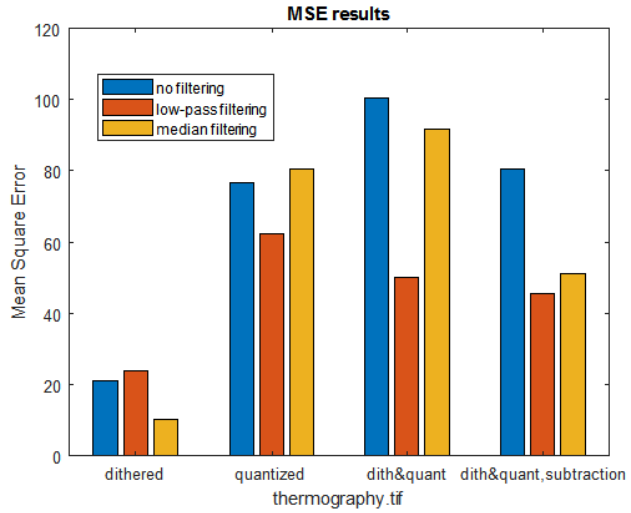

FIGURE 19. MSE results of the "thermography.tif" image with eight levels of quantization.

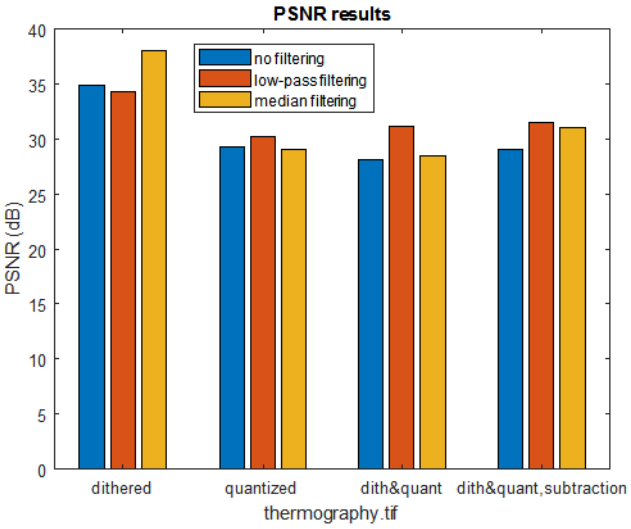

FIGURE 20. PSNR results of the "thermography.tif" image.

quantized with subtraction methods offer better MSE and peak signal-to-noise ratio (PSNR) results than others. For example, with "mammo.tif" image, the median filtering with the dithered lower MSE (12.8028) and hence the higher PSNR (37.0262) than others as illustrated in Figures 15 and 16 respectively. Other than the dithering method, the filtering with the dithered, quantized with subtraction methods offers lower MSE (31.0835) and hence the higher PSNR (33.0835) than others as shown in Figures 15 and 16 respectively. Similarly, the MSE and PSNR results with the "angiogram.tif" are shown in Figures 17 and 18 respectively. Also, the MSE and PSNR results of the "thermography.tif" image are obtained in Figures 19 and 20 respectively.

IV. CONCLUSION

This study exemplifies the significance of dithering technique with biomedical test images. The dithering fundamentals along with the quantization, dithered and quantization, dithered and quantization with subtraction and the filtering with each one being demonstrated. The sole objective of the dithering is to break up the contouring effect. Since the noise is added, there will be a poor performance with higher MSE. The better performance can be achieved by introducing the filtering kernel at the end. That is, the PSNR metric can be raised with the aid of filtering. This work can further be extended to the color images. This work can further be extended appropriately to other domains such as brain signal processing and analysis, automatic detection and diagnosis of neurologic diseases, pattern recognition, machine learning, etc [15]–[18].

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