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Dvadasham (Dodeca) Edge Filter for Impulse Noise, Gaussian Noise, Quantum Noise Reduction in Images

(A Generic Image Filter)

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***Abstract*:** All image processing techniques need to extract meaningful information from images. However, the noise generated during image acquisition and transmission degrades the human interpretation, or computer-aided analysis of these images. Therefore, denoising should be performed to improve the image quality for more accurate analysis and diagnosis, So we thought of designing a generic image filter that can be applicable to remove Impulse noise, Gaussian noise, Quantum noise. In this paper we propose a novel image denoising technique Dvadasham (Dodeca) Edge Filter (DEF). We applied this filter on various images, obtained the results by measuring parameters like Standard Deviation, Homogeneity and compared it with the results of existing Fuzzy Filter. The results obtained with DEF are quite promising than Fuzzy Filter.

Keywords: Noise Reduction, Denoising, DEF, Dvadasham, Dodeca, Image Filter, Edge Detection, Fuzzy filter, Impulse Noise, Gaussian Noise, Quantum Noise.

I. INTRODUCTION

Image processing [1] [2] is a technique in which the data from an image are digitized and various mathematical operations are applied to the data, generally with a digital computer, in order to create an enhanced image that is more useful or pleasing to a human observer, or to perform some of the interpretation and recognition tasks usually performed by humans.

In the field of image processing image filtering plays a dominant role, in which a particular filtering technique will be employed by manipulating the image pixels in order to remove or reduce the irrelevant or unexpected patterns in the image. The main reason for excessive use of image filter is due to noise. The Image noise is random (not present in the object imaged) variation of brightness or color information in images, and is usually an aspect of electronic noise. So it is highly desirable to develop an effective filter which can remove 100% noise, although it is quite impossible.

The need of image filtering is more intense in the field of medical science than any other field. Since medical imaging instruments itself produce some amount of noise due to hardware and circuit limitations (such as capacitors, registers, display unit etc..,) the analysis by physician may become imperfect. The noise generally present in these images will be categorized as quantum noise which is unavoidable.

In fact, edge detection is very important in the field of Computer Vision, Image Processing viz. feature detection and feature extraction in which the image brightness changes sharply [3]. Objective of image processing is to identify points at which there is a sharp change in an image [4]. Changes can be due to discontinuity in depth, variations in color, variations in scene illumination or a sharp change in brightness [5]. Edges characterize object boundaries and are therefore useful for segmentation, registration, and identification of objects in an image [6]. The accuracy of the edges highly depends on the lighting conditions, presence of similar intensity objects, and presence of the noise.

The main challenge is to distinguish edges from other small features in the image such as textures and especially the noise, so that all edges are detected accurately, while the noise is suppressed. Accuracy of the edges i.e. sharpness falls drastically with the presence of the noise and high rate of color variations, which is common in any real world image.
We organized all the above thoughts and developed a novel generic image filter called Dvadasham (Dodeca) Edge filter

(DEF) that can be used for removing Impulse noise, Gaussian noise, and Quantum noise in the medical images thus serving for social cause.

II. NOISES IN IMAGE

Image noise is the random variation of brightness or color information in images produced by the sensor and circuitry of a scanner or digital camera. Image noise can also originate in film grain and in the unavoidable shot noise of an ideal photon detector. Image noise is generally regarded as an undesirable by-product of image capture. Although these unwanted fluctuations became known as "noise".

Gaussian noise is statistical noise that has its probability density function equal to that of the normal distribution, which is also known as the Gaussian distribution. In other words, the values that the noise can take on are Gaussian-distributed. A special case is white Gaussian noise, in which the values at any pair of times are identically distributed and statistically independent (and hence uncorrelated). In applications, Gaussian noise is most commonly used as additive white noise to yield additive white Gaussian noise [7] [11].

The Impulse noise (or salt and pepper noise) is caused by sharp, sudden disturbances in the image signal; its appearance is randomly scattered white or black (or both) pixels over the image [8] [9]. Noise filtering can be viewed as removing the noise from the corrupted image and smoothen it so that the original image can be viewed, or replacing every pixel in the image with a new value. Ideally, the filtering algorithm should vary from pixel to pixel based on the local context [9].

In almost all medical imaging techniques (radiography, CT scan, MRI, fluoroscopy etc.,) a light beam (photons) will be projected towards the patient and collected back using a receptor plane [10]. The amount of quantum noise in images will be dependent on number of photons collected at the receptor plane. When large amount of photons are projected towards patient, the noise will be reduced but patient will be highly exposed to the radiation. In contrast if less radiation is used the photon fluctuation in the image will be increased this photon fluctuation is what actually called Quantum Noise.

III. METHODOLOGY

In this section we discuss in detail about the new proposed DEF Filter and in brief about Fuzzy Filter [12]. The architecture of the proposed system for filters DEF and Fuzzy Filter is shown in the Fig. 3.1. Both Filters will be applied iteratively by considering 3X3 Kernel (shown in Fig. 3.2) of the grayscale image and identifying the neighbors in all eight directions from 3X3 Kernel for the intended centre pixel (x, y) shown in Fig. 3.2.

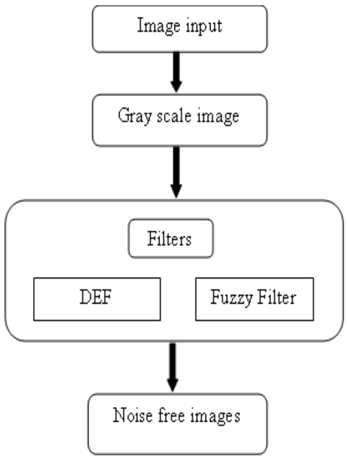


Fig.3.1. Architecture of the proposed system for filters DEF and Fuzzy Filter.

NW	*N*	*NE*
W	*(x,y)*	*E*
SW	*S*	*SE*

Fig.3.2. Neighbors in all eight directions from 3X3 Kernel for the intended centre pixel (x,y).

A. *Dvadasham (Dodeca) Edge Filter (DEF)*

DEF is mainly designed to identify the presence of edges and checking the intensity value of intended pixel is due to noise or image structure. Initially we identify the presence of edges in the surrounding of the intended centre pixel (x, y) by checking the pixel intensity values in 12 different directions for 3X3 Kernel shown in the Fig. 3.3.

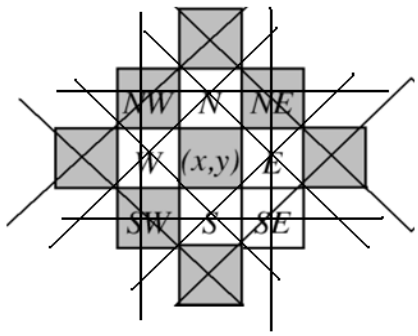


Fig.3.3. Edges in the surrounding of the intended centre pixel (x,y) in 12 different directions for 3X3 Kernel.

To check the intensity value of intended centre pixel (x, y) value is due to noise or image structure, we calculate the Mean [2] [3] [4], Median [2] [3] [4] values for 3X3 Kernel. We will determine the Mean Difference and Median Difference by substracting the intended centre pixel (x, y) (current pixel (C)) value with Mean and Median respectively.

To calculate new pixel intensity value for current pixel (C) we will compare Mean Difference and Median Difference with current pixel (C) as follows.

If Mean Difference and Median Difference is greater than C, Possibility of Noisy pixel intensity might be there, So we will change the pixel value by,

Set Pixel Value (P) = (Mean Difference – Median Difference) + C.

Else If Mean Difference and Median Difference is less than C,

Possibility of No noisy pixel, So we will change the pixel value by,

Set Pixel Value (P) = Mean Difference + Median Difference + C.

Else If Mean Difference is greater and Median Difference is less than C,

Possibility of Noisy pixel with very high intensity value might be there, So we will change the pixel value by,

Set Pixel Value (P) = Mean Difference + C.

Else If Mean Difference is less and Median Difference is greater than C,

Possibility of Noisy pixel with low intensity value might be there, So we will change the pixel value by,

Set Pixel Value (P) = Median Difference + C.

Else

Set Pixel Value (P) = (Mean Difference + Median Difference + C)/3.

In this approach we avoid replacing of current pixel (C) by Mean or Median. In case of Mean there might be chance smoothening by the addition of undesired pixel intensity due to Averaging in 3X3 Kernel neighbor pixels. In case of Median there might be chance of blurring of image due to the replacement of actual pixel intensity by Median value in 3X3 Kernel neighbor pixels.

ALGORITHM

The overall process of the DEF filter is conveyed through algorithm as below
//Input: Grayscale image (m rows and n columns) and number of iterations (I)
//Output: Filtered image

Step 1: Read the Input Grayscale Image m rows and n columns.
Step 2: For t = 0 and t = I iterations
Step 3: For each pixel get the 3X3 Kernel by determining Neighbor pixel values.

To preserve the boundary pixel values of an image replace border pixel value (null values or no information) of image to Current Pixel Value (C).

Calculate Mean value for 3X3 Kernel.

Calculate Median value for 3X3 Kernel.

Calculate Mean Difference = Mean – C.

Calculate Median Difference = Median – C.

If Mean Difference and Median Difference is greater than C,

Set Pixel Value (P) = (Mean Difference – Median Difference) + C.

Else If Mean Difference and Median Difference is less than C,

Set Pixel Value (P) = Mean Difference + Median Difference + C.

Else If Mean Difference is greater and Median Difference is less than C,

Set Pixel Value (P) = Mean Difference + C.

Else If Mean Difference is less and Median Difference is greater than C,

Set Pixel Value (P) = Median Difference + C.

Else

Set Pixel Value (P) = (Mean Difference + Median Difference + C)/3.

Check for the 12 edges present in the 3X3 Kernel. If edge is present,

Set Pixel Value (P) = (P + C)/2.

End For.

Check the number of iterations and set current image for next iteration.

End For.

B. Fuzzy Filter

In this approach we have referred and used the existing Fuzzy Filter [11][12] [15].The general idea behind the filter is to average a pixel using other pixel values from its neighborhood, but simultaneously to take care of important image structures such as edges. The main concern of the proposed filter is to distinguish between local variations due to noise and due to image structure. In order to accomplish this, for each pixel we derive a value that expresses the degree in which the derivative in a certain direction is small. Such a value is derived for each direction corresponding to the neighboring pixels of the processed pixel by a fuzzy rule [11] [12].

The further construction of the filter is then based on the observation that a small fuzzy derivative most likely is caused by noise, while a large fuzzy derivative most likely is caused by an edge in the image. Consequently, for each direction we will apply two fuzzy rules that take this observation into account (and thus distinguish between local variations due to noise and due to image structure), and that determine the contribution of the neighboring pixel values. The result of these rules (16 in total) is defuzzified and a "correction term" is obtained for the processed pixel value [11] [12].

IV. EXPERIMENTAL RESULTS AND ANALYSIS

In this section, the proposed DEF algorithm is evaluated and compared with Fuzzy Filter technique by measuring the parameters Standard Deviation (σ)and Homogeneity (μ) [12] [13] [14].

Homogeneity provides an estimate of noise density in terms of remaining amount of noise in an image. To compute Homogeneity equation 4.1, we start by dividing the image in small NxN non overlapping blocks. For each block B, we compute a rough measure for the Homogeneity of this block by considering the maximum and minimum pixel intensity (I) value and L represents the number of gray levels [12].

$$\mu = 1 - \frac{\max_{(x,y)\in B} I(x,y) - \min_{(x,y)\in B} I(x,y)}{L}. \tag{4.1}$$

To calculate the Standard Deviation (σ), first we need to determine the Mean (M) value each block (B) equation 4.2. The standard deviation is the most common measure of variability, measuring the spread of the data set (pixel intensity values (I)) and the relationship of the Mean to the rest of the data. If the data points (pixel intensity values (I)) are close to the Mean, indicating that the responses are fairly uniform, and then the standard deviation will be small. Conversely, if many data points (pixel intensity values (I)) are far from the Mean, indicating that there is a wide variance in the responses, then the standard deviation will be large. If all the data values (pixel intensity values (I)) are equal, then the standard deviation will be zero. The standard deviation is calculated using the following formula equation 4.3.

$$M = (\sum_{i=0}^{N} I(x,y))/N \tag{4.2}$$

Where, N = Number of pixels in 3X3 Kernel.

$$\sigma = \sqrt{(\sum_{i=0}^{N} (I(x,y)-M)\times(I(x,y)-M)) \div N} \tag{4.3}$$

Where, N = Number of pixels in 3X3 Kernel.

I(x, y) = Intensity current pixel.

M = Mean value of 3X3 Kernel.

Using a statistical model for the noise distribution, we know that there is a linear relationship between the Homogeneity and the Standard Deviation [12] [14]. When Standard Deviation is higher the amount of noise density will be greater. When Homogeneity is lower the amount noise density will be greater.

The proposed filtering system is applied to grayscale test images (8-bit, L=255), after adding Impulse Noise, Gaussian Noise and Quantum Noise of different levels. The Table I show the comparisons of the results obtained for various images with different noises.

TABLE I. SHOWS COMPARISONS OF THE RESULTS OBTAINED FOR FILTERED IMAGES, ORIGINAL IMAGES AND NOISY IMAGES

Images		DEF			Fuzzy Filter		
		Number of Iterations	Standard Deviation	Homogeneity	Number of Iterations	Standard Deviation	Homogeneity
Lena (Gaussian Noise)	Original	-	13.6342	0.7933	-	13.6342	0.7933
	Noisy	-	17.6046	0.7062	-	17.6046	0.7062
	Filtered	2	13.252	0.782	2	10.615	0.837
		8	10.743	0.830	8	10.334	0.844
		12	9.942	0.846	12	10.18	0.849
		16	9.362	0.858	16	10.166	0.849
Medical6 (Quantum Noise)	Original	-	5.367	0.9288	-	5.367	0.9288
	Noisy	-	9.2517	0.8586	-	9.2517	0.8586
	Filtered	2	8.316	0.878	2	8.891	0.868
		8	7.109	0.898	8	8.823	0.8693
		12	6.57	0.906	12	8.809	0.8695
		16	6.113	0.913	16	8.802	0.8696
Aeroplane (Impulse Noise)	Original	-	8.2954	0.8867	-	8.2954	0.8867
	Noisy	-	15.0842	0.7537	-	15.0842	0.7537
	Filtered	2	12.695	0.798	2	11.332	0.8323
		8	10.953	0.833	8	10.916	0.8433
		12	10.356	0.846	12	10.877	0.8444
		16	9.902	0.855	16	10.849	0.8451

In case of the Gaussian Noise we have considered the Lena Image after applying the DEF and Fuzzy Filter, the performance of both filters is measured by Statistical parameters such as Standard Deviation and Homogeneity. For 16 number of iterations, DEF $\sigma = 9.362$, $\mu = 0.858$, and Fuzzy Filter $\sigma = 10.166$, $\mu = 0.849$. So, DEF results quite promising one when compared to Original Image refer Fig. 4.1., Fig.4.2.

(a) (b)

(c) (d)

Fig.4.1. Snapshots of output results (a) Original Lena Image, (b) With Gaussian Noise, (c) DEF Image, (d) Fuzzy Filter Image.

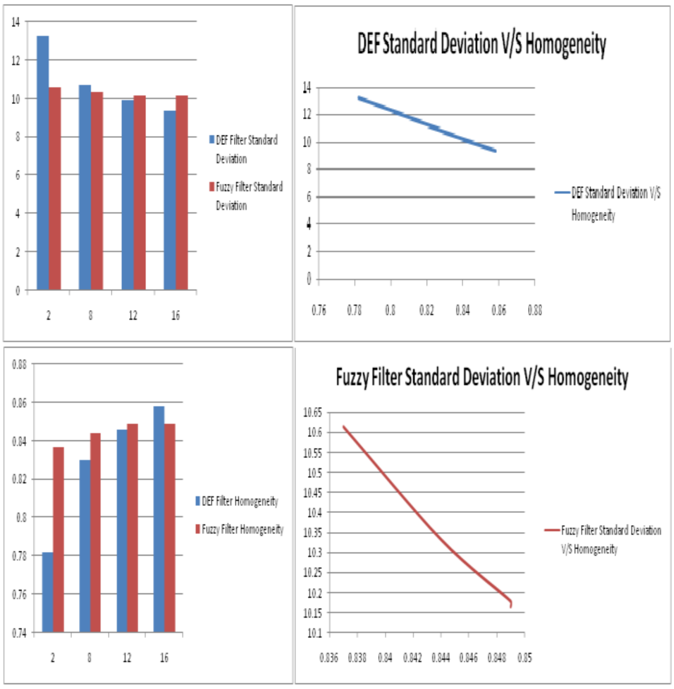
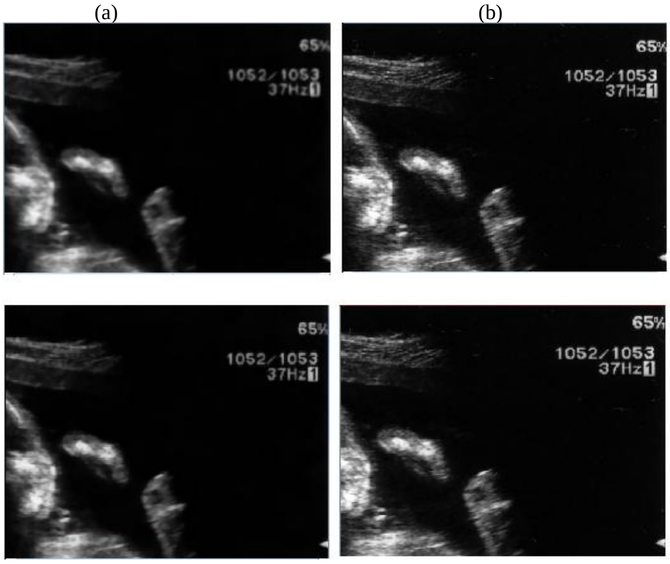


Fig.4.2. Graphical comparision of Statistical Parameters (Standard Deviation and Homogeneity) of Gaussian Noise reduction with DEF and Fuzzy Filter.

In case of the Quantum Noise we have considered the Medical Image after applying the DEF and Fuzzy Filter, the performance of both filters is measured by Statistical parameters such as Standard Deviation and Homogeneity. For 16 number of iterations, DEF $\sigma = 6.113$, $\mu = 0.913$, and Fuzzy Filter $\sigma = 8.802$, $\mu = 0.8696$. So, DEF results quite promising one when compared to Original Image refer Fig. 4.3., Fig.4.4.

(a) (b)



(c) (d)

Fig.4.3. Snapshots of output results (a) Original Medical Image, (b) With Quantum Noise, (c) DEF Image, (d) Fuzzy Filter Image.

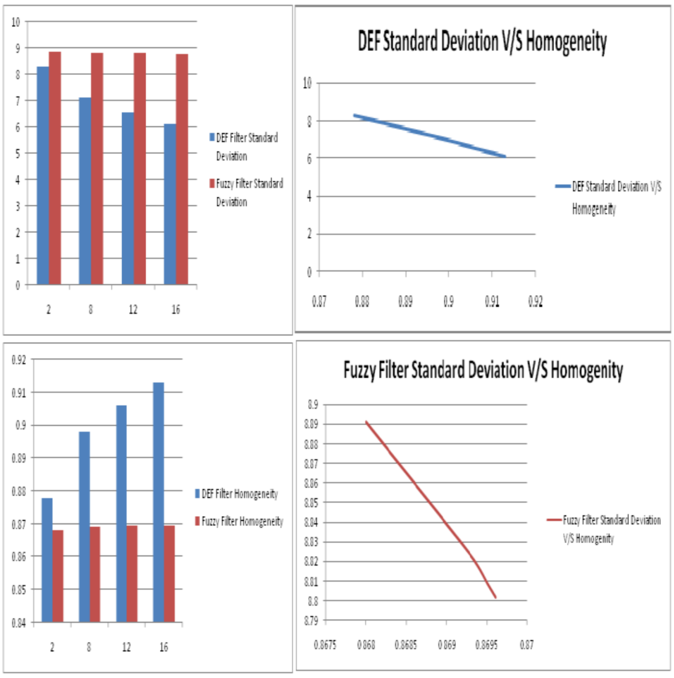
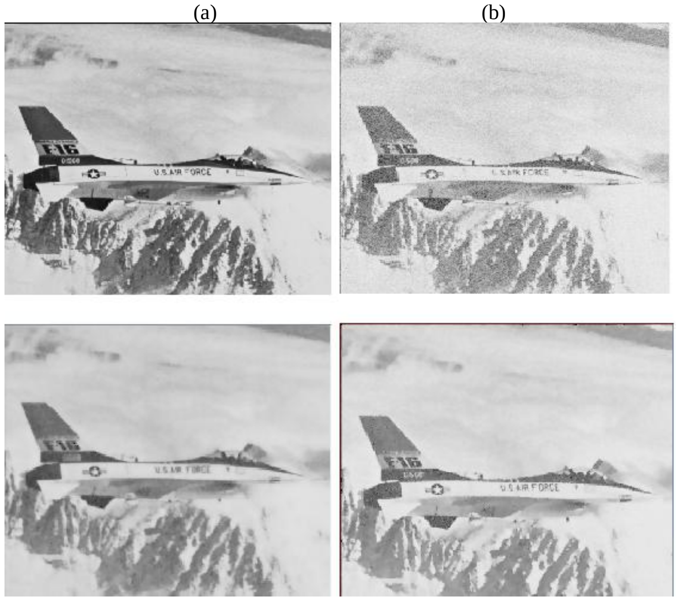


Fig.4.4. Graphical comparision of Statistical Parameters (Standard Deviation and Homogeneity) of Quantum Noise reduction with DEF and Fuzzy Filter.

In case of the Impulse Noise we have considered the Aeroplane Image after applying the DEF and Fuzzy Filter, the performance of both filters is measured by Statistical parameters such as Standard Deviation and Homogeneity. For 16 number of iterations, DEF $\sigma = 9.902$, $\mu = 0.855$, and Fuzzy Filter $\sigma = 10.849$, $\mu = 0.8451$. So, DEF results quite promising one when compared to Original Image refer Fig. 4.5., Fig.4.6.

(a) (b)



(c) (d)

Fig.4.5. Snapshots of output results (a) Original Aeroplane Image, (b) With Impulse Noise, (c) DEF Image, (d) Fuzzy Filter Image.

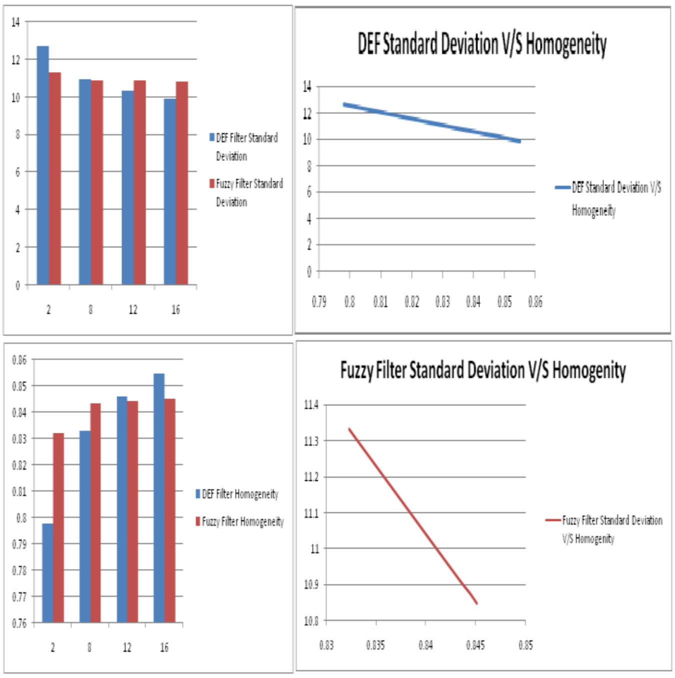


Fig.4.6. Graphical comparision of Statistical Parameters (Standard Deviation and Homogeneity) of Impulse Noise reduction with DEF and Fuzzy Filter.

V. Conclusion

As discussed in the abstract there are no filters which can reduce different type of noises. In this paper we have presented a new filter DEF which can eliminate maximum amount of noise meanwhile preserving the edges in the image. When compared to Fuzzy Filter, DEF offers good results as discussed in section IV. But still there is need for maintaining the image quality.

VI. Scope

On successful implementation and deployment of this project to the work environment, it will have the direct impact on the image processing and analysis field, space and satellite applications field, medical field. Because of the drawbacks that, practically measuring instruments in different applications cannot provide 100% noise free images, there is a desperate need of image filters that can reduce different noises. Our newly designed image filter DEF is capable of reducing Gaussian Noise, Quantum Noise and Impulse Noise, thereby serving a social cause.

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