Noise Reduction of Ultrasound Image Using Wiener filtering and Haar Wavelet Transform Techniques

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Abstract

Background: Noise reduction of the medical image is an important task to improve the medical image quality that may be helpful in medical diagnosis.

Methods: The proposed system performed into two steps: First; application of Wiener filtering technique as a preprocessing step to reduce amount of noise present in ultrasound image of human kidney, Second; implementation of Haar wavelet transform for denoising the resulted image from the first step.

Results: The results of noise isolation of ultrasound image after implementation of Wiener filtering and wavelet transform were presented. also; some statistical results of these images were recorded.

Conclusions: We deduced that Wiener filtering and Haar wavelet techniques are efficient and powerful in reducing the noises form ultrasound images. Matlab package (version 7.3) was used in writing the programming codes of this study.

Keywords: Ultrasound image, Wavelet transform , Wiener filtering, De-noising.

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Introduction

Ultrasound imaging has become a popular modality because it is safe, noninvasive, portable, relatively inexpensive, and provide a real time image formation. However, the fundamental problem of ultrasound images is the poor quality , mainly caused by multiplicative speckle noise[1,2].

Speckle noise is a random mottling of the image with bright and dark spots which obscures fine details and degrades the delectability of low-contrast lesions. Speckle noise occurrence is often undesirable, since it affects the tasks of human interpretation and diagnosis. On the other hand, its texture carries important information about the tissue being imaged. Speckle filtering is thus a critical pre-processing step on medical ultrasound imagery, provided that the features of interest for diagnosis are not lost. The small differences that may exist between normal and abnormal tissues are confounded by noise and artifacts, often making direct analysis of the acquired images difficult[3] .

The field of image processing is a huge one . it encompasses, at the very least, the following areas: 1. Image compression; 2. Image Denoising; 3.Image enhancement ; 4. Image recognition; 5. Feature detection; 6. Texture classification. Wavelet bases techniques can be applied to all of these topics · Image enhancement techniques are mathematical techniques that are aimed at realizing improvement in the quality of a given image. The result is another image that demonstrates certain features in a manner that is better in some sense as compared to their appearance in the original image[3,4]. By virtue of its multi-resolution representation capability, the wavelet transform has been used effectively in vital applications such as computer vision[5].

In this study, the proposed system included using of Wiener filtering as a pre-processing step and Haar wavelet transform for improvement the quality of kidney ultrasound image for the purpose of image denoising. The results section of this paper presented region description of resulted improved ultrasound images that were obtained from implementation of Wiener filtering and wavelet techniques. The discussion of the results of both techniques are presented. Finally conclusions were drawn from this study.

Methods and Subjects

From May 2009 to October 2010, (10) cases were selected from patients attending Baghdad teaching hospital . these cases were considered in our study.

Wiener Filtering :

There are two powerful techniques to reduce the noise level in signal; Wiener filtering [6] and wavelet thresholding [7].Wiener filter provides the best restored signal with respect to the square error averaged over the original signal and the noise among (linear operator)[8]

Wiener filters are characterized by the following [9]:

- Assumption: signal and (additive) noise are stochastic processes with known spectral characteristics or known autocorrelation and cross-correlation
- Performance criteria: minimum mean-square error
- An optimal filter can be found from a solution based on scalar methods

It is based on a statistical approach. Its purpose is to reduce the amount of noise present in a signal by comparison with an estimation of the desired noiseless signal.

The principle of the Wiener filter is defined as an operator that minimizes a mean square error (MSE) between a restored signal and the original signal. It is averaged in respect to both

the original signal and noise.

Let E_f and E_n be ensemble means with respect to the original signals and noise respectively. Then the Wiener filter X_{WF} is defined as[10]:

$$\min_X J_{WF}(X) = E_f E_n \left\| f - \hat{f} \right\|^2 = E_f E_n \left\| f - Xg \right\|^2 \quad \text{……….(1)}$$

Where $\|.\|$ denotes a norm defined by $\|f\| = \sqrt{<f,f>}$ and $<.,.>$ denotes inner product . The Neumann-Shatten product of *f* and *g* is defined by:

$$\left(f \otimes \overline{g}\right)h = \langle h, g \rangle f \quad \text{………...(2)}$$

Where *h* is an arbitrary vector. Let the correlation operators *R* and *Q* be:

$$R = E_f\left(f \otimes \overline{f}\right) \quad \text{...............(3)}$$

$$Q = E_n\left(n \otimes \overline{n}\right) \quad \text{……….(4)}$$

Then the solution of the Wiener filter X_{WF} is given as follows:

$$X_{WF} = RA^*(ARA^* + Q)^\dagger \quad \text{………(5)}$$

Where $*$ denotes an adjoin operator and $\dagger$ enotes an Moore-Penrose (Pseudo) inverse operator.

Wavelet Transform:

Wavelet are a tool for hierarchically decomposing functions. They allow a function to be described in term of a coarse overall shape, plus details that range from broad to narrow mathematical. Regardless of whether the function of interest is an image , a curve, or a surface, wavelet offer an elegant technique for representing the levels of details present .Wavelet are developed in applied mathematics for the analysis of multiscale image structures. Wavelet functions are distinguished from other transformations such as Fourier transform because they not only dissect signals into their component frequencies but also vary the scale at which the component frequencies are analyzed. As a result, wavelets are exceptionally suited for applications such as data compression, noise reduction, and singularity detections in signals. The ability to vary the scale of the function as it addresses different frequencies also makes wavelet better suited to signals with spikes or discontinuities than traditional transformations such as the Fourier transforms. The applications of wavelet to medical image enhancement has been extensively studied and starts recently to be applied [3,11] .

Haar Wavelet :

The Haar wavelet is the first known wavelet and was proposed by Alfred Haar in 1909. It is the simplest of all wavelets and its operation is easy to understand. Haar wavelets have their limitations too. They are piecewise constant and hence produce irregular, blocky approximations[12].The Haar wavelet transform has a number of advantages that can be summarized as follow [13]:

- It is conceptually simple.
- It is fast
- It is memory efficient, since it can be calculated in place without a temporary array.
- It is exactly reversible without the edge effects that are a problem with other wavelet transforms.

Two-dimensions Haar Wavelet Transform:

Let Y={Y_i}, (i=0,….,2^M-1, 2^M=N‹∞, M ∈ N), be a real square sum able de-noised, time-series $Y \in K^N \subset \ell^2$ (where K is real field): $t_i=i/2^M-1$ is regular equispaced grid of dyadic points on the interval restricted for convenience and without restriction on [0;1]; its family of translated and dilated scaling function is introduced as [11]:

$$\begin{cases} \varphi_k^n = 2^{n/2}\varphi\left(2^n t-k\right), \quad \left(0\le n, 0\le k\le 2^n-1\right) \\ \varphi_k^n\left(2^n t-k\right)=\begin{cases}1, t\in\Omega_k^n, \Omega_k^n=\left[\frac{k}{2^n},\frac{k+1}{2^n}\right) \\ 0, t\notin\Omega_k^n\end{cases}\end{cases} \quad ....(6)$$

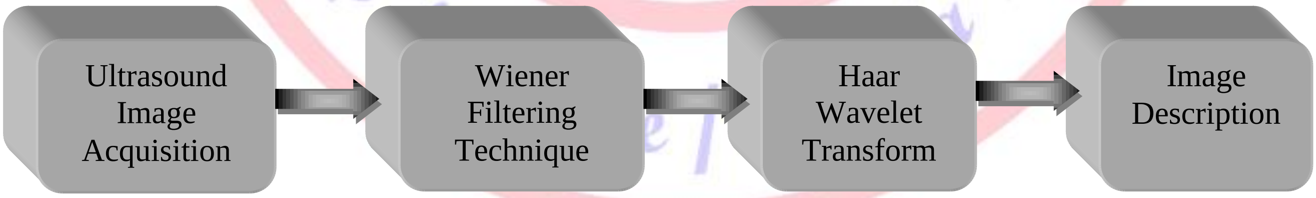
The Haar wavelet $\{\Psi_k^n(t)\}$ family is an orthonormal basis for L^2 ([0; 1] functions[12] :

$$\begin{cases} \Psi_k^n(t) \equiv 2^{n/2}\Psi(2^n t - k), \quad \left\|\Psi_k^n\right\|_{L^2} = 1 \\ \Psi_k^n(t) = \begin{cases} -2^{-n/2}, & t \in \left[\frac{k}{2^n}, \frac{k+1/2}{2^n}\right) \\ 2^{-n/2}, & t \in \left[\frac{k+1/2}{2^n}, \frac{k+1}{2^n}\right), (0 \le n, 0 \le k, \le 2^n - 1) \\ 0, & elsewhere \end{cases} \end{cases} \quad \ldots\ldots\ldots\ldots(7)$$

Although, without loss of generality, we restrict over selves to $0 \le n$, $0 \le k \le 2^n \rightarrow [0;1]$, for other integer values of k the family Haar scaling functions and wavelets are defined also outside $[0;1]$ making possible to extend the following consideration to any interval of R [12].

Proposed System:

In this study, the proposed system of noise reduction from ultrasound image of human kidney was explained below (figure 1). All theories and algorithms that were needed and used in implementation of this system were described in the previous sections. The first stage of the proposed system was an image acquisition. This stage was performed through collection of 10 cases from patients attending Baghdad teaching hospital at the same period of the study. These images characterized by containing different types of noise and artifacts that result from different sources. Thus, in order to remove these noise and artifacts we first applied Wiener filtering technique on these images as a preprocessing step of noise reduction and isolation. Then we applied Haar wavelet transform on the resulted images from the previous preprocessing step . The effects of these two methods on ultrasound images processing were presented in the results and discussion sections. The proposed system of noise reduction of ultrasound image can be summarized by the following diagram:



Figure(1): The Proposed System.

Results and Discussions

1. **Weiner filtering technique:**

The ultrasound image of human kidney shown in figure (1.a) represented an input image to the proposed system of this study. As we said previously, ultrasound image is characterized by the presence of noise and artifacts and this can be detected by studying the histogram of an input ultrasound image which was shown in figure (1.b). As you know the medical images are complex images and the presence of such noise and artifacts makes the problem of ultrasound image interpretation more difficult. The first step of this study (application of Wiener filtering technique) resulted in an image that was shown in figure (1.c).One can notice that there is an improvement in an image quality . At this stage Wiener filtering act as a reducer of the noises that was presented in the original (input) ultrasound image. Here, I want to bring your attention to that, we can use another types of filters (such as median filter) but we preferred the Wiener filtering since it give a great SNR (which is equals to 27.3453 in our study) without blurring the regions of interest that may be not obtained with the another types of filters.

Figure (1.a): An original image.

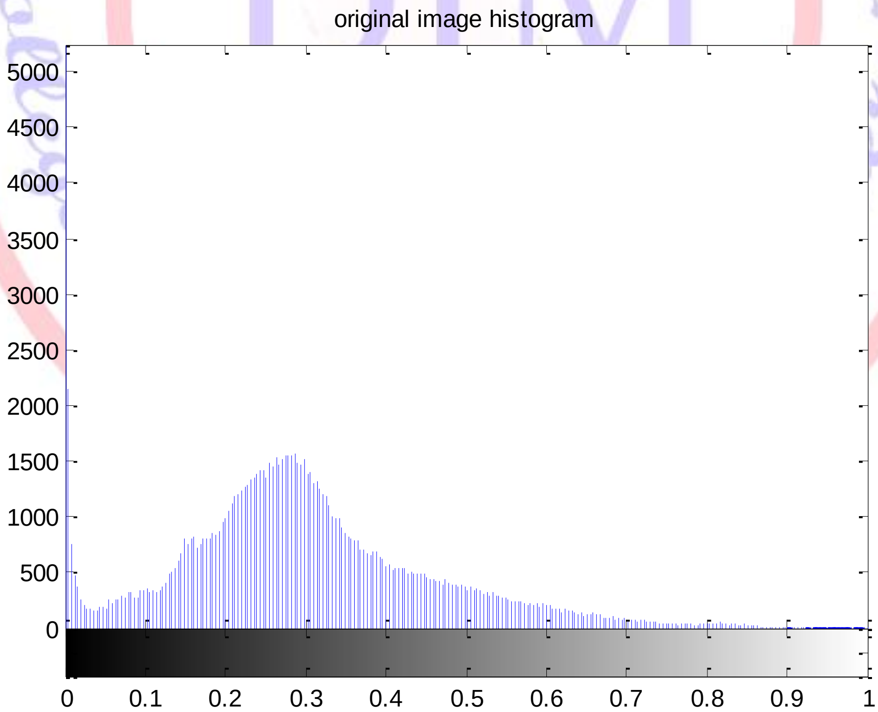


Figure (1.b): Histogram of an original image.

Figure (1.c): Image after Wiener filtering.

Figure(1.d): show the histogram of ultrasound image after Wiener filtering .See the smoothness of the histogram that result from noise reduction in an image.

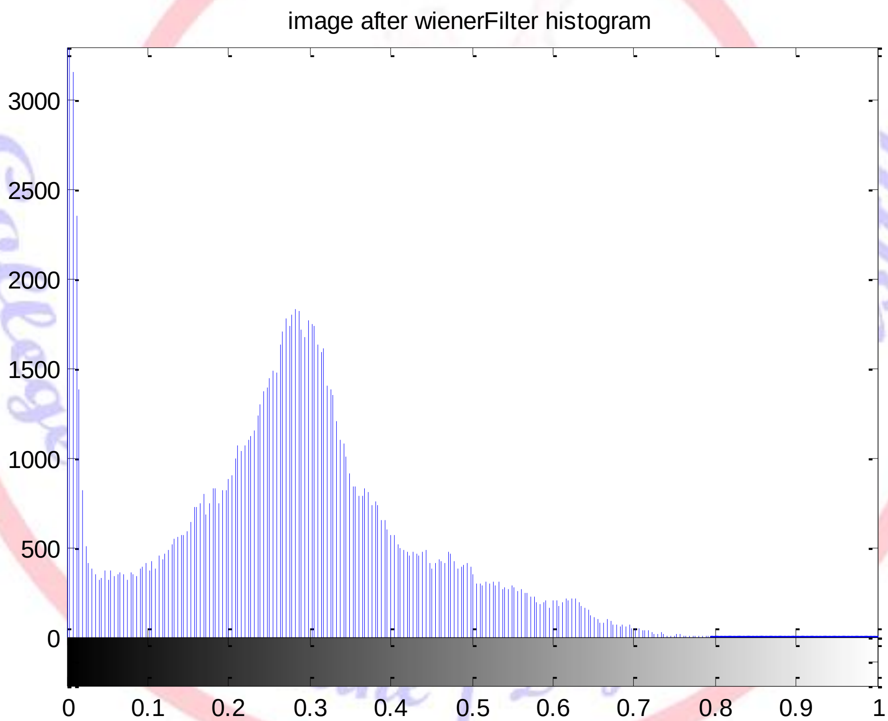


Figure (1.d): Histogram of ultrasound image after Wiener filtering.

2. Haar wavelet transform:

We considered ultrasound kidney image in figure (1.c) as an input image to perform two dimensional Haar wavelet transform. After implementation of Haar wavelet transform we obtained an image in figure (2.a). One can realize that there is noticeable improvement and noise reduction of an input image to this stage. When we subtracted the origin (input) image from that in figure (2.a) we obtained the a mount of remaining noise (figure (2.b). This remaining noise needs another filtering process to remove it (we will perform it as a future work in advance research).The histogram of an enhanced image in figure (2.a) was shown in figure (2.c).

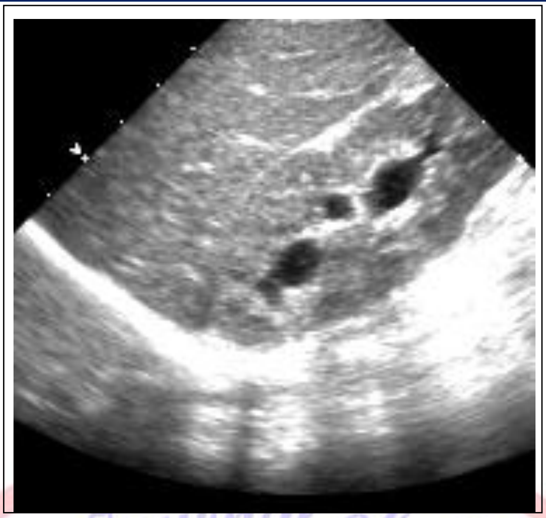


Figure (2.a): Image after Haar wavelet transform implementation.

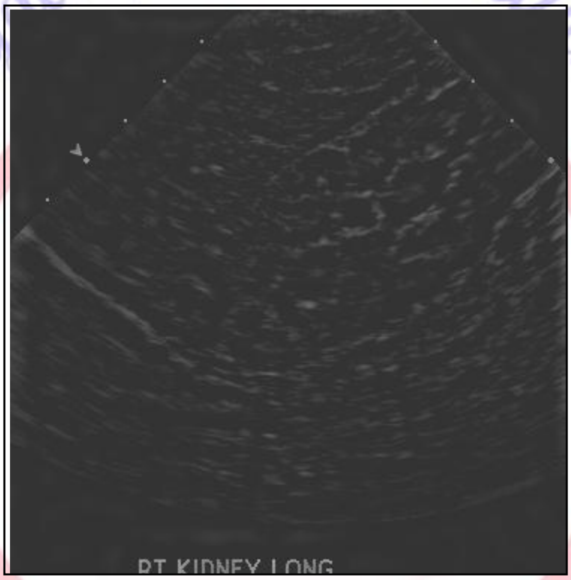


Figure (2.b): The residual noise.

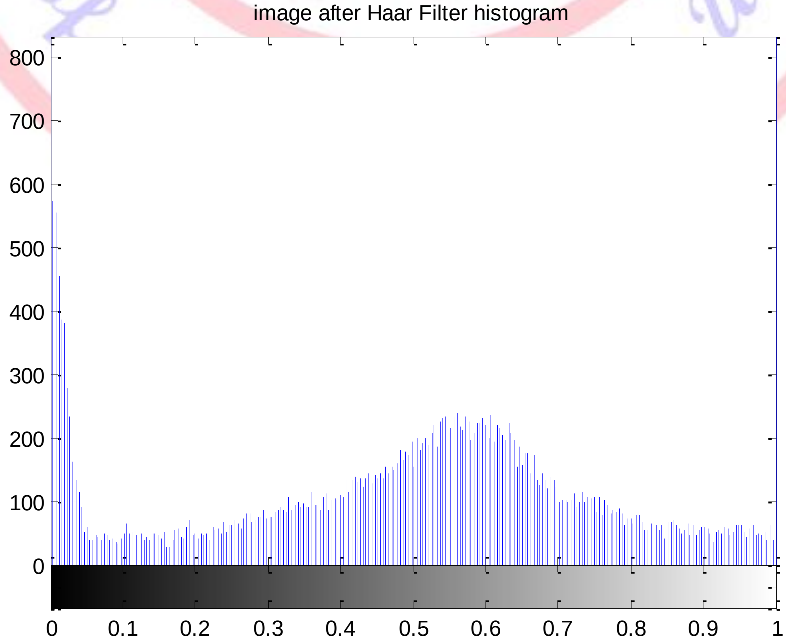


Figure (2.c): Histogram of ultrasound image after Haar transformation.

3.Statistical Results:

In this section we presented the values of mean and variance of an original image, the resulted image after Wiener filtering implementation, and the resulted image after Haar transform application, see table (3.1). One can notice that the value of mean after each step of noise reduction procedure was increased since there is gradual increasing in the brightness of these images thus image after Haar transform applications was recorded the highest value(figure (3.a)).The values of variance showed that the value of an enhanced image by Haar transform had the highest value because of its high smoothness (figure (3.b)).

Table (3.1): Mean and variance values.

	Mean	Standard Deviation
Original image	0.23295	0.03486
Image after Wiener filtering	0.23633	0.03017
Image after Haar transformation	0.46235	0.10191

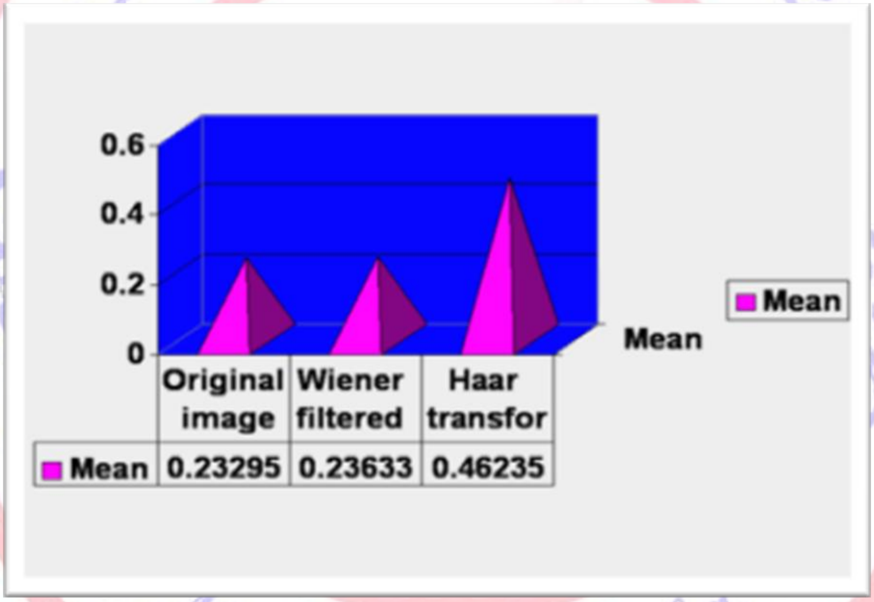


Figure (3.a): Mean Value.

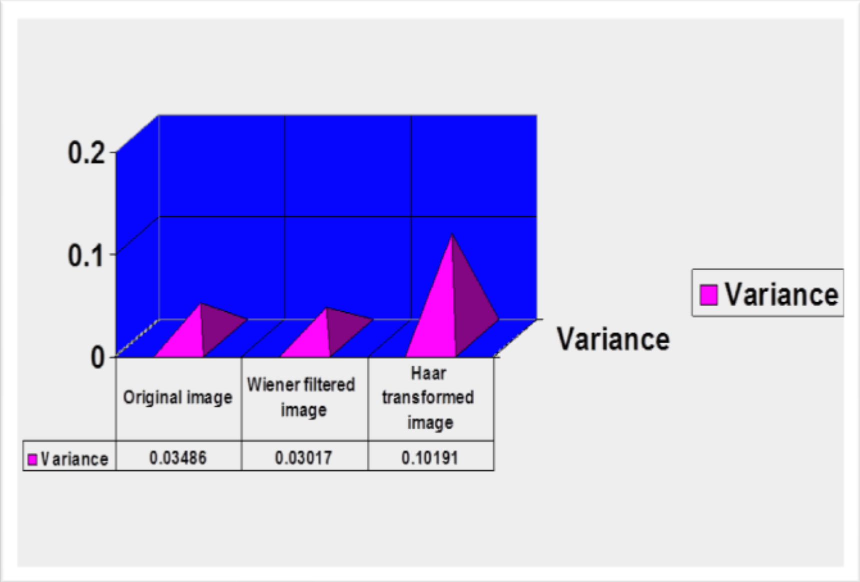


Figure (3.b): Variance Value.

Conclusions

After implementation of the proposed system for ultrasound images noise reduction of the human kidney, we deduced several conclusions that are: ultrasound is one of the simplest method that used in providing information that are of great helpful in the medical diagnostic field. We present an ultrasound image noise reduction method that based on filtering (using Wiener filter) and non-linear processing wavelet transform (using Haar wavelet transform).The obtained experimental results show that the proposed system of our study considerably increase and enhance the ultrasound image quality without generating any noticeable noise or artifact that if it present in an image, it result in poor quality image. Also, the proposed system could be adapted to be implemented for enhancement purpose of other biomedical images.

After implementation of Wiener filtering algorithm, we deduced that: in Wiener filtering, the noise and artifact are reduced well and structures of the tissue images were enhanced, but some details are lost and some are over-enhanced. Also, we found that Wiener filtering removes the noise pretty well in smooth regions but performs poorly along the edges. By using Wiener filter, the noise is reduced well but the image edges are intact, also the images are sharper; i.e. (Wiener filtering could be considered as the better techniques in reducing the noise without fully eliminated the image edges).The implementation of Wiener filtering algorithm is not as sophisticated as other methods that used in field of biomedical images improvement.

Depending on our experimental results, Haar wavelet transform is a simple method due to its low computing requirements , thus it has been mainly used in fields of image processing and pattern recognition. Also, it is an efficient tool in ultrasound image denoising. By using Haar wavelet technique, the kidney ultrasound image kept its details and sharpness.

References

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