# PRESERVING EDGE INFORMATION OF A SATELLITE IMAGE USING DWT

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***Abstract*— Images are being processed in order to obtain super enhanced resolution. Resolution is one of the important attributes of an image. In this paper, a method is proposed to enhance the visibility of the given image. Based on the interpolation of the high frequency subbands obtained by DWT and the input image, a new resolution enhancement technique is to be implemented. The proposed resolution enhancement technique uses DWT to preserve the high frequency components of the image. DWT decomposes the image into LL,LH,HL,HH subband images. Then, the high frequency subband images and the low resolution input image have been interpolated, followed by combining all these images by using inverse DWT to generate a new resolution enhancement image. In order to preserve more edge information, an intermediate stage in high frequency subband interpolation process is proposed. The results show the superiority of the proposed technique over conventional methods.**

**Key words: Image Resolution, Image Interpolation, Wavelet Zero Padding, Discrete Wavelet Transform, Stationary Wavelet Transform**

## I. INTRODUCTION

Nowadays, satellite images are used in many applications such as geo science studies, astronomy. The principal objective of enhancement technique is to process an image so that the result is more suitable than the original image for a specific application. Image enhancement process is one of the most interesting and visually appealing areas of image processing. Image enhancement approaches fall into two categories: spatial domain methods and frequency domain methods. The term spatial domain refers to the image plane itself, and the approaches in this category are based on direct manipulation of pixels in an image. Frequency domain processing methods are based on modifying the Fourier transform of an image. There is no general theory of image enhancement process. When an image is processed for visual interpretation, the viewer is the ultimate judge of how well a particular method works. One of the most important quality factors in images is resolution. Interpolation is a well known method to increase resolution of a digital image. Interpolation has been widely used in many image processing applications such as facial reconstruction and resolution enhancement.

Many interpolation techniques have been developed to increase the image resolution of a digital image. There are three well known techniques to implement interpolation, namely, nearest neighbor interpolation, bilinear interpolation and bicubic interpolation. Bilinear interpolation considers the closest 2x2 neighborhood of known pixel values surrounding unknown pixel's computed location. Then, it takes a weighted average of these 4 pixels to arrive at its final, interpolated value. Bicubic goes one step beyond bilinear interpolation by considering the closest 4x4 neighborhood of known pixels, for a total of 16 pixels. Since these are at various distances from unknown pixel, closer pixels are given a higher weighting in the calculation. Bicubic interpolation produces noticeably sharper images than the bilinear interpolation. In this paper, many new algorithms for image-resolution enhancement in the wavelet domain have been proposed. Discrete wavelet Transform (DWT) is one of the recent wavelet transforms used in image processing. Wavelets are playing a key role in many image processing applications. The 2-D wavelet decomposition of a digital image is performed by applying the 1-D discrete wavelet transform along the rows of the image first, and then the results are decomposed along the columns. This operation results in four subband images referred to Low-Low (LL), Low-High (LH), High-Low(HL),and, High-High(HH). Fig. 1 shows the block diagram of DWT filter banks of level 1.

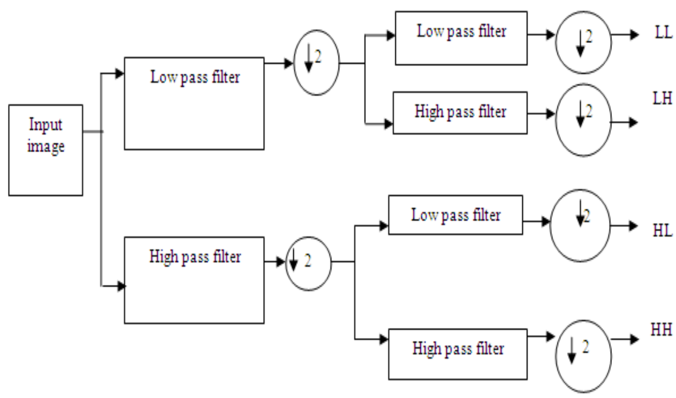


Fig. 1: Block diagram of DWT filter banks of level1

 

In this paper, a resolution-enhancement technique using interpolated DWT high-frequency subband images and the low-resolution input image is proposed. Inverse DWT has been applied to combine all these images to generate the final resolution-enhanced image. In order to achieve a sharper image, an intermediate stage for estimating the high frequency subbands by utilizing the difference image obtained by subtracting the input image and its interpolated LL subband is proposed. The proposed technique has been compared with standard interpolation techniques like bilinear, bicubic interpolation, Wavelet Zero Padding (WZP)[1].

## II. BILINEAR INTERPOLATION

In image processing and computer vision, bilinear interpolation is one of the basic resampling techniques. In texture mapping, it is also referred as 'bilinear filtering' or 'bilinear texture mapping', and it can be used to produce a reasonably realistic image. An algorithm is used to map a screen pixel location to a corresponding point on texture map. A weighted average of the attributes of the four surrounding pixels is computed and applied to the screen pixel. This entire process is repeated for each pixel forming the object being textured. When an image needs to be scaled up, each pixel of the original image needs to be moved in a certain direction based on the scale constant value. However, when scaling up an image by a non-integral scale factor, there are pixels, that are not assigned appropriate pixel values.

In this case, those pixels should be assigned appropriate RGB or grayscale values so that the output image does not have non-valued pixels. Bilinear interpolation can be used in applications, where perfect image transformation with pixel matching is impossible, so that one can calculate and assign appropriate intensity values to pixels. Unlike other interpolation techniques such as nearest neighbor interpolation and bicubic interpolation, bilinear interpolation uses only 4 nearest pixel values which are located in diagonal directions from a given pixel in order to find the appropriate color intensity values of that pixel.

Bilinear interpolation considers the closest 2x2 neighborhood of known pixel values surrounding unknown pixel's computed location. Then, it takes a weighted average of these 4 pixels to arrive at its final, interpolated value. The weight on each of the 4 pixel values is based on the computed pixel's distance (in 2D space) from each of the known points. The above algorithm reduces some of the visual distortion caused by resizing an image to a non-integral zoom factor, as opposed to nearest neighbor interpolation, which will make some pixels appear larger than others in the resized image[2]. Bilinear interpolation tends, however, to produce a greater number of interpolation artifacts (such as aliasing, blurring) than more computationally demanding techniques such as bicubic interpolation.

## III. BICUBIC INTERPOLATION

In mathematics, bicubic interpolation is an extension of cubic interpolation for interpolating data points on a 2_D regular grid. The interpolated surface is smoother than corresponding surfaces obtained by bilinear or nearest-neighbor interpolation. Bicubic interpolation can be accomplished using either cubicsplines, or cubic convolution algorithm. In image processing, bicubic interpolation is chosen over bilinear interpolation or nearest neighbor in image resampling, when speed is not an issue. Images resampled with bicubic interpolation are smoother and they have fewer interpolation artifacts. Bicubic goes one step beyond bilinear interpolation by considering the closest 4x4 neighborhood of known pixels, for a total of 16 pixels. Since these are at various distances from unknown pixel, closer pixels are given a higher weighting in the calculation.

Bicubic interpolation produces noticeably sharper images than the bilinear interpolation, and is perhaps an ideal combination of processing time and output quality. For this reason, it is a standard technique in many image editing programs (including Adobe Photoshop), printer drivers.

## IV. WAVELET ZERO PADDING

Using a given image x of size mxn, the high resolution image y is obtained by using zero padding of high frequency subbands (that is setting all elements of these subbands to zero), followed by inverse Wavelet Transform.

## V. WAVELET BASED IMAGE RESOLUTION ENHANCEMENT

There are several different methods which have been used for satellite image resolution enhancement. In this paper, we have used conventional techniques like bilinear and bicubic interpolation and WZP, for comparison purposes.

### *A Image Resolution Enhancement by using Discrete and Stationary Wavelet Decomposition*

In the process of image resolution enhancement by using interpolation, the main loss is on its high frequency components (i.e., edges) of an image, which is due to the smoothing caused by interpolation. In order to increase the visibility of the super resolved image, preserving the edges is essential. In this paper, DWT has been employed in order to preserve the high frequency components of an image. The redundancy and shift invariance of the DWT mean that DWT coefficients are inherently interpolable.

In this correspondence, 1 level DWT (with Daubechies 9/7 as wavelet function) is used to decompose an input image into different subband images. The three high frequency subbands (LH, HL, and HH) contain the high frequency components of the input image. Then, bicubic interpolation with enlargement factor of 2 is applied to high frequency subband images. Down sampling in each of the DWT subbands causes information loss in the respective subbands. This is the reason for employing Stationary Wavelet Transform (SWT) to minimize this loss.

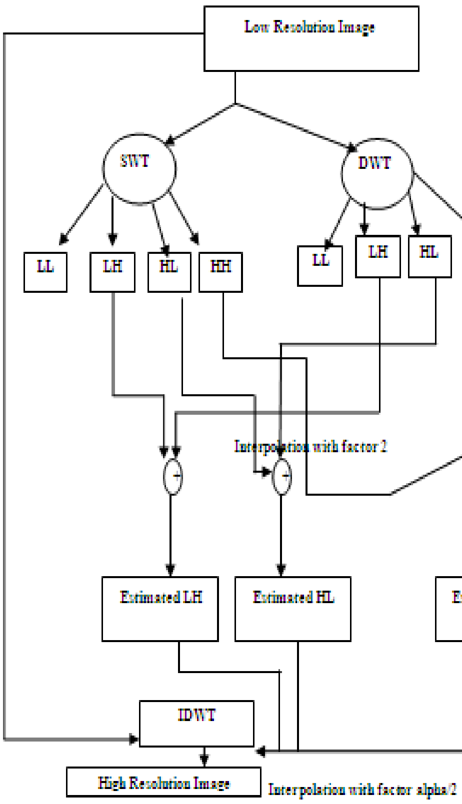


Fig. 2:Block Diagram of image resolution enhancement by using Discrete and Stationry Wavelet Decomposition

The interpolated high frequency subbands and the SWT high frequency subbands have the same size which means they can be added with each other. The new corrected high frequency subbands can be interpolated further for higher enlargement. Also it is known that in the wavelet domain, the low resolution input image is obtained by low pass filtering of the high resolution image. Therefore, instead of using low frequency subband, which contains less information than the original high resolution image, we are using the input image for the interpolation of low frequency subband image. Using input image instead of low frequency subband increases the quality of the super resolved image. Fig. 2 illustrates the block diagram of the image resolution enhancement technique using discrete and stationary wavelet decomposition[3].

By interpolating input image by ‘alpha/2’ and high frequency subbands by 2 and ‘alpha’ in the intermediate and final interpolation stages respectively, and then by applying IDWT, as illustrated in Figure 2, the output image will contain sharper edges than the interpolated image obtained by interpolation of input image directly. This is due to the fact that, the interpolation of isolated high frequency components in high frequency subbands and using the corrections obtained by adding high frequency subbands of SWT of the input image, will preserve more high frequency components after the interpolation than interpolating input image directly.

*B. Proposed Resolution Enhancement Technique*

Resolution is an important feature in satellite image processing, which makes the resolution enhancement of such images to be of great importance as increasing the resolution of these images will directly affect the performance of the system using these images as input. The main loss of an image after being resolution enhanced by applying interpolation is on its high frequency components, which is due to the smoothing caused by interpolation technique. Hence, in order to increase the visibility of the enhanced image, preserving the edges is essential.

In this technique, DWT has been introduced in order to preserve the high frequency components of the image. DWT separates the image into four subband images, namely, LL, LH, HL, and HH. High frequency subbands contains the high frequency component of the given image. The interpolation can be applied to these four subband (LL,LH,HL,HH)images. In the wavelet domain, the low resolution input image is obtained by low-pass filtering of the high resolution image. The low resolution image (LL), without quantization (i.e., with double precision pixel values) is used as the input for the proposed resolution enhancement process. In other words, low frequency subband images are the low resolution of the original input image. Therefore, instead of using low frequency subband images directly, which contains less information than the original input image, we are using this input image through the interpolation process[4].

 

Fig. 3 illustrates the block diagram of the proposed image resolution enhancement technique.

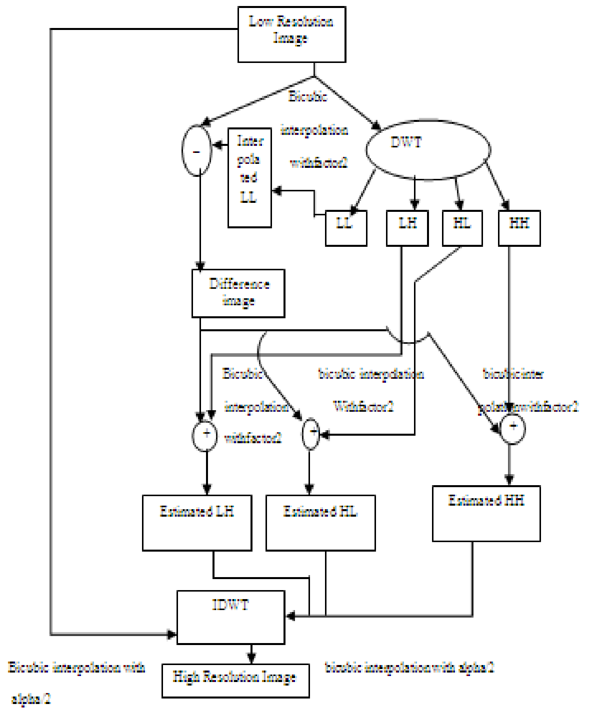


Fig. 3:Block Diagram Of Image Resolution Enhancement by Using Discrete Wavelet Transform

Hence, the low-resolution input image is interpolated with the half of the interpolation factor, $\alpha/2$, used to interpolate the high frequency subbands, In order to preserve edge information, i.e., obtaining a sharper enhanced image, we have proposed an intermediate stage in high frequency subband interpolation process. The low resolution input satellite image and the interpolated LL image with factor 2 are highly correlated. The difference between the LL subband image and the input low resolution image are in their high-frequency components. Hence, this difference image can be used in the intermediate stage to correct the estimated high-frequency components. This estimation is achieved by interpolating the high-frequency subbands by factor 2 and then including the difference image (which is high-frequency components on low-resolution input image) into the estimated high-frequency images, followed by another interpolation with factor $\alpha/2$ in order to reach the required size for IDWT process. The intermediate process of adding difference image, containing high frequency components, generates significantly sharper and clearer final image[5]. If we use the method of Interpolation of Wavelet Domain High Frequency Subbands and the Spatial Domain Input Image, we get better results than the proposed method[6].

## VI. SIMULATION RESULTS

The proposed technique has been tested on different satellite images. In order to show the superiority of the proposed method over the conventional techniques from visual point of view fig. 4,fig. 5,fig. 6 are included. In those figures with low resolution satellite images, the enhanced images by using bilinear, bicubic interpolation, enhanced images by using WZP and also the enhanced images obtained by the proposed technique are shown. It is clear that the resultant output image, enhanced by using the proposed technique, is sharper than the other techniques[7].


(a)


(b)


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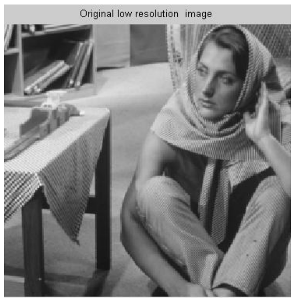
(d)


(e)


(f)


(g)

Fig. 4: Results for Lena Image (a) Low-resolution image obtained from down sampling of the high-resolution satellite image through two cascaded DWT, (b)Bilinear interpolation based resolution enhancement (c)Bicubic interpolation-based resolution enhancement, (d)Super resolved image using WZP, (e) Image resolution enhancement technique, using DWT and SWT (f) DWT based image resolution enhancement (g)Super resolution image using DWT and spatial domain input image




(a)


(b)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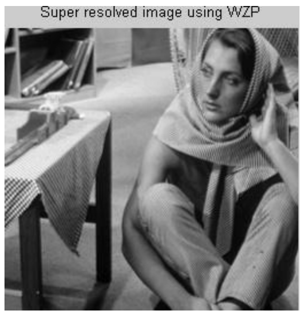



(d)

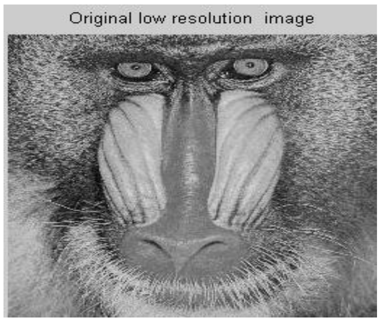
 


(e)

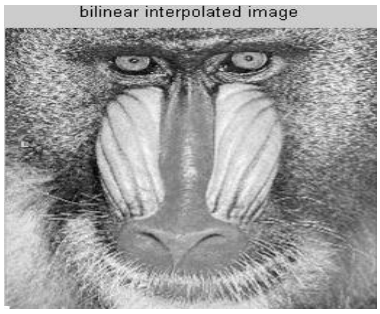

(f)


(g)

Fig. 5: Results for Barbara Image (a) Low-resolution image obtained from down sampling of the high-resolution satellite image through two cascaded DWT, (b)Bilinear interpolation based resolution enhancement (c)Bicubic interpolation-based resolution enhancement, (d) Super resolved image using WZP, (e) Image resolution enhancement technique, using DWT and SWT (g) DWT based image resolution enhancement (h)Super resolution image using DWT and spatial domain input image




(a)

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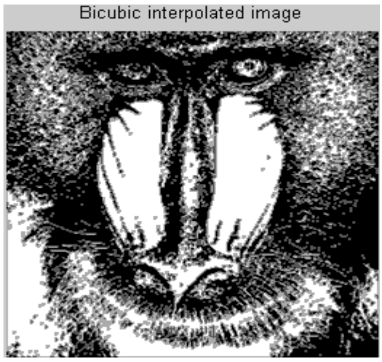


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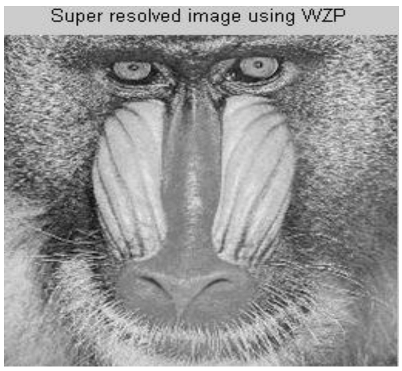
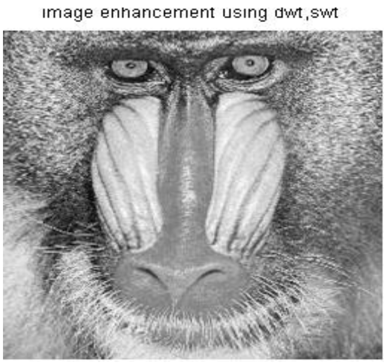
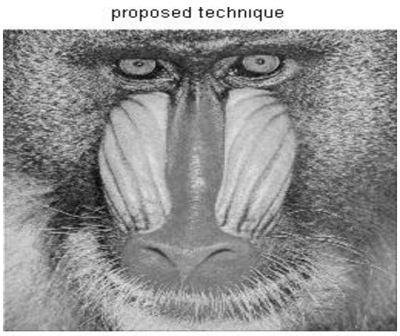



(d)

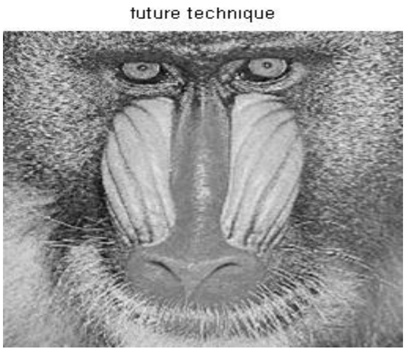
 




(e)




(f)




(g)

Fig. 6: Results for Lena Image (a) Low-resolution image obtained from down sampling of the high-resolution satellite image through two cascaded DWT, (b)Bilinear interpolation based resolution enhancement (c)Bicubic interpolation-based resolution enhancement, (d) Super resolved image using WZP, (e) Image resolution enhancement technique, using DWT and SWT (g) DWT based image resolution enhancement (h)Super resolution image using DWT and spatial domain input image

Not only visual comparison but also quantitative comparisons are confirming the superiority of the proposed technique. Peak signal-to-noise ratio (PSNR) and root mean square error (RMSE) have been implemented in order to quantitative results for comparison. PSNR can be obtained by using the following formula

$$PSNR = 10\log (R^2/MSE) \qquad (1)$$

where *R* is the maximum fluctuation in the input image (255 in here as the images are represented by 8 bit, i.e., 8-bit grayscale representation have been used_radiometric resolution is 8 bit); and MSE is representing the mean square error between the given input image *Iin* and the original image *Iorg* which can be obtained by the following formula

$$MSE = \sum_{i,j}(I_{in}(i, j) - I_{org}(i, j))^2/(M \times N) \qquad (2)$$

Where M and N are the size of the images. And, Clearly, RMSE is the square root of MSE[8].

TABLE 1
PSNR (DECIBLES) RESULTS FOR RESOLUTION ENHANCEMENT OF AN IMAGE USING DIFFERENT TECHNIQUES

| Technique | Value of PSNR in db | | |
|---|---|---|---|
| | **Barbara** | **Lena** | **Baboon** |
| Bilinear Interpolation | 53.3475 | 52.1389 | 51.7691 |
| Bicubic Interpolation | 55.3707 | 54.1833 | 53.8018 |
| Wavelet Zero Padding | 60.5456 | 59.4665 | 59.1031 |
| Image Resolution Enhancement Using DWT and SWT | 60.9428 | 59.7795 | 59.3194 |
| Image Resolution Enhancement Using DWT | 61.2648 | 60.0725 | 59.6899 |
| Image Super Resolution Based on Interpolation of Wavelet Domain High Frequency Subbands and the Spatial Domain Input Image | 61.2892 | 60.0894 | 59.7065 |

Table I is showing the comparison of PSNR value in db between the proposed method using haar wavelet transform with bilinear interpolation, bicubic interpolation and some resolution enhancement techniques, such as WZP.

TABLE 1I
MSE RESULTS FOR RESOLUTION ENHANCEMENT OF AN IMAGE USING DIFFERENT TECHNIQUES

| Technique | Value of MSE | | |
|---|---|---|---|
| | Barbara | Lena | Baboon |
| Bilinear Interpolation | 0.5485 | 0.6304 | 0.4327 |
| Bicubic Interpolation | 0.4345 | 0.4982 | 0.2710 |
| Wavelet Zero Padding | 0.2395 | 0.2712 | 0.0799 |
| Image Resolution Enhancement Using DWT and SWT | 0.2288 | 0.2616 | 0.0761 |
| Image Resolution Enhancement Using DWT | 0.2204 | 0.2529 | 0.0698 |
| Image Super Resolution Based on Interpolation of Wavelet Domain High Frequency Subbands and the Spatial Domain Input Image | 0.2198 | 0.2524 | 0.0696 |

Table II is showing the comparison of MSE value between the proposed method using haar wavelet transform with bilinear interpolation, bicubic interpolation and some resolution enhancement techniques, such as WZP.

TABLE 1II
RMSE RESULTS FOR RESOLUTION ENHANCEMENT OF AN IMAGE USING DIFFERENT TECHNIQUES

| Technique | Value of RMSE | | |
|---|---|---|---|
| | Barbara | Lena | Baboon |
| Bilinear Interpolation | 0.5485 | 0.6304 | 0.6578 |
| Bicubic Interpolation | 0.4345 | 0.4982 | 0.5205 |
| Wavelet Zero Padding | 0.2395 | 0.2712 | 0.2827 |
| Image Resolution Enhancement Using DWT and SWT | 0.2288 | 0.2616 | 0.2758 |
| Image Resolution Enhancement Using DWT | 0.2204 | 0.2529 | 0.2643 |
| Image Super Resolution Based on Interpolation of Wavelet Domain High Frequency Subbands and the Spatial Domain Input Image | 0.2198 | 0.2524 | 0.2638 |

Table III is showing the comparison of RMSE value between the proposed method using haar wavelet transform with bilinear interpolation, bicubic interpolation and some resolution enhancement techniques, such as WZP.

## VI.CONCLUSION

This paper has proposed a new resolution enhancement method based on the interpolation of the high-frequency subband images obtained by DWT and the input image. The proposed technique has been tested on well-known benchmark images (lena,Barbara,Baboon etc), where their PSNR and visual results show the superiority of the proposed technique over the conventional techniques.

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