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Watermarking Flat HDR images using Symlet

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ABSTRACT

Tampering and reproducing an image today is as easy as writing on walls. Image editing tools have made it easier to play around with any image. To protect the hard work of the original designer it is very important to protect rights of the originator and that is only possible if the original image is ascertained. To say the picture is original or a replica is as difficult as finding a needle in hay; even age-old watermarking techniques have failed in many cases. Protecting a digital image becomes even tougher as it is easy to manipulate. In this paper, a method for watermarking on Flat High Definition images has been proposed using DWT (Sym12).

Keywords: HDR, Tonemap, watermarking, DWT, 2-D DCT, Symlet

Introduction

1.1 Watermarking

Methods and techniques that are used to hide information, like test in an image or in a video or an image in an image or image text in audio is termed as Digital Watermarking [1]. The implanting takes place by operating the content of the ordinal data, that is, the information is not attached in the frame of the data. The hiding process has to be such that the modifications of the media are unnoticeable. If we are using images, the values of the modified image after appending data should not be visible. Furthermore, the watermark must be either strong or insubstantial, depending on the application. Strong means that the capability of the watermark to repel manipulations of the media, such as cropping, compression and more. In some cases, the watermark may need to be insubstantial [2]; means that the watermark should not resist tampering, or should resist only up to some level. A simple example to demonstrate digital watermarking is shown in Fig. 1.1. It can be seen that after the watermarking the originality of the image remains almost same.

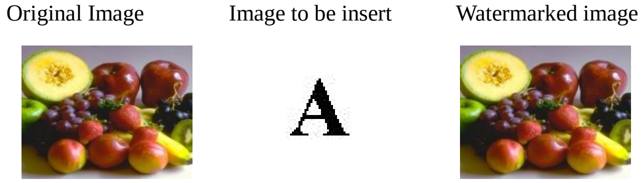


Figure.1.1. Watermarking image Demonstration

1.2 Techniques

Numbers of techniques were proposed in the past like DCT, DWT, Hybrid DCT and DFT [3-7] for colored images but not much work has been done on HDR images. With the advancement of digital communication, it is very important to provide technique to watermark HDR images too. 2D DCT is an easy and robust method to watermark images we have used 2D DCT to watermark HDR images too.

1.2.1 DCT

The discrete cosine transform (DCT) assist to isolate the image in to chunks we can say spectral sub-bands of diverge significance considering the quality of the image. It is somewhat like discrete Fourier transform: it changes a signal or image from the spatial domain to the frequency domain. The discrete cosine transform (DCT) represents an image as a sum of sinusoids of varying magnitudes and frequencies. The equation of 1D DCT is

$$F(u)=\left(\frac{2}{N}\right)^{\frac{1}{2}}\sum_{i=0}^{N-1}\Lambda(i).\cos\left[\frac{\Pi.u}{2.N}(2i+1)\right]\quad f(i) \tag{1}$$

and the corresponding inverse 1D DCT transform is simple $F^{-1}(u)$, where

$$\Lambda(i)=\begin{cases}\frac{1}{\sqrt{2}} & for \quad \xi=0\\ 1 & otherwise\end{cases} \tag{2}$$

The general equation for a 2D (N by M image) DCT is defined by the following equation:

$$F(u,v)=\left(\frac{2}{N}\right)^{\frac{1}{2}}\left(\frac{2}{M}\right)^{\frac{1}{2}}\sum_{i=0}^{N-1}\sum_{j=0}^{M-1}\Lambda(i)\Lambda(j).\cos\left[\frac{\Pi.u}{2N}(2i+1)\right]\cos\left[\frac{\Pi v}{2M}(2j+1)\right].f(i,j) \tag{3}$$

and the corresponding inverse 2D DCT transform is simple F-1(u,v), i.e.: where

$$\Lambda(\xi)=\begin{cases}\frac{1}{\sqrt{2}} & for \quad \xi=0\\ 1 & otherwise\end{cases} \tag{4}$$

The elementary operations are:

- The input image is N by M
- f(i,j) is the intensity of the pixel in row i and column j;
- F(u,v) is the DCT coefficient in row k1 and column k2 of the DCT matrix.
- For most images, much of the signal energy lies at low frequencies; these appear in the upper left corner of the DCT.
- Compression is achieved since the lower right values represent higher frequencies, and are often small - small enough to be neglected with little visible distortion.
- The DCT input is an 8 by 8 integer matrix. Every pixel's gray scale level is stored in this matrix
- 8 bit pixels have levels from 0 to 255.

1.2.2 HDRI

HDR or HDRI refers to High-Dynamic-Range-Imaging /imager. We can say the production of high dynamic images from digital images is HDRI. High dynamic range (HDR) imaging has been an active research area in the last two decades. Dynamic range is the ratio between the least and the highest values of a physical measurement. In real-world scenarios, one might encounter a wide range of luminance (up to 9log units) between the highlights and the shadows. The HDR format, originally known as the Radiance picture format (.hdr, .pic), was first introduced as part of the Radiance lighting simulation and rendering system in 1989 [8]; and has since found widespread use in the graphics community, particularly for HDR photography and image-based lighting [9,10].HDR rendering algorithms; which are also known as tone-mapping operators are designed to scale the large range of luminance information that exists in the real world so that it can be displayed on a device that is only capable of producing a much lower dynamic range. There are other encodings like -tiff, LogLuv, exr. IEEE float, scRGB48, scRGBnl, and scYCC-nl.

1.2.3 Tonemap

It is the method of converting high dynamic images to low dynamic images. The range of light we experience in the real world is vast, spanning approximately ten orders of absolute range from glittering scenes to sundrenched snow, and over four orders of dynamic array from shades to highpoints in a single scene. However, the array of shades we can reproduce on our print and screen display devices spans at best about two orders of absolute dynamic range. This discrepancy leads to the tone reproduction problem. A great deal of work has been done on the tone reproduction problem [12]. Most of this work has used an explicit perceptual model to control the operator [13]. Such methods were extended to dynamic and interactive settings [14]. Other work has focused on the dynamic range compression problem by spatially varying the mapping from scene luminance to display luminance while preserving local contrast [15]. Finally, computational models of the human visual system can also guide such spatially-varying maps [16].

1.2.4. Wavelet

Wavelet is a wave type of oscillation that begins with amplitude at zero, rises, and then comes back to zero. Seismograph, heart monitors, oscillators show these types of waves. For signal processing purpose, wavelets are intentionally fashioned to have defined properties. Techniques like, integration, multiplication, shifting and reversing are combined together with convolution can be applied over a segment of a known signal to get information from the unknown signal. As a mathematical tool, wavelets can help to extract information from different types of data like - image, signal or audio. It could be used, to extract features or even compress multimedia data for research purpose. Wavelets have found ways in various application like face recognition, character recognition, voice recognition, emotion recognition from voice and image and many more; we can say wavelet is limited only by the scanty knowledge of the user on its own it is huge. The wavelets are generated from a single basic wavelet ψ(t), the so-called mother wavelet, by scaling and translation:

$$\psi_{s,\tau}(t) = \frac{1}{\sqrt{s}}\psi\left(\frac{t-\tau}{s}\right) \tag{4.1}$$

In (5.1) s is the scale factor, is the translation factor and the factor s-1/2 is for energy normalization across the different scales.

1.2.4.1Discrete Wavelet Transform (DWT)

Discrete wavelets are not continuously scalable and translatable but can only be scaled and translated in discrete steps[19]. This is achieved by modifying (4.1) the wavelet representation to create

$$\psi_{j,k}(t) = \frac{1}{\sqrt{s_0^j}}\psi\left(\frac{t-k\tau_0 s_0^j}{s_0^j}\right) \tag{5}$$

Although it is called a discrete wavelet, it normally is a (piecewise) continuous function. In (5.1) j and k are integers and s0 > 1 is a fixed dilation step. The translation factor -0 depends on the dilation step. The effect of discretizing the wavelet is that the time-scale space is now sampled at discrete intervals. We usually choose s0 = 2 so that the sampling of the frequency axis corresponds to dyadic sampling. This is a very natural choice for computers, the human ear and music for instance.

$$\int \Psi_{j,k}(t)\Psi^*_{m,n}(t)dt = \int \begin{matrix} 1 if\ j=m & and & k=n \\ 0 & otherwise & \end{matrix} \tag{5.1}$$

Inverse of discrete wavelet

$$f(t) = \sum_{j,k}\gamma(j,k)\Psi_{j,k}(t) \tag{6}$$

1.2.5.1 Reading HDR images

There are various methods for reading HDR images Matlab has an in-built method to read images. For this research in-built function of Matlab was used to read HDR images and for Flat HDR images[17] following method was used

```
fl← open file in read mode
[filetype,noofbits] ← get format of fl     /* 8 or 16 bit, rgbe or xyze type */
fsensor← get information of fl             /* get wavelength and spectral */
flluminant← get Illumination of fl
himage← make image readable                /* read 8 bit or 16 bit data, reshape and
create new Low intensity image */
[himage, Gluminance] ← convert high dynamic to low dynamic range using
Reinhard global tone map algo[18]
```

(7)

2 Methodology

Sticking to the basics of watermarking the HDR images were first tone mapped to low dynamic range images the experiment was done without changing the image to low dynamic range but the output becomes totally dark. Once the images were changed to low dynamic images,DWT and DCT techniques were applied and images were watermarked. A graphical user interface was designed in Matlab for the experimental purpose. Following algo describes the technique better.

2.1 Steps to water mark using 2D-DCT / DWT

```
Read flat HDR images using (7)
Use (3)/(5) on read image
Use (3) /(5) on image to be marked
Reshape Original image
Push image to be marked in the original image
Apply (4)/(6) to inverse
Reshape image to original size
```

2.1.1 Algorithm for DCT on HDR

```
Initialize required variables
  I ← Read hdr image using                  (7)
 Wtg ← read image to hide
 Timage ← tonemap I
  Imgrey ← Timage to gray
  Imgra ← resize imgray to m X m
 wmr← resize wtg to n X n
 dct_img ← blkprocess imgray for each 8X8 block using
 2-D dct
  for i ← 1 to m step 8
         for j ← 1 to m step 8
             for I ←i to i+7
               idr ← increment by one
               for J ←j to ij+7
                  idc ← increment by 1
                  z[dr,dc] ← dct[I,J];
                end for
                     idc ← 0
             end for
             x(k) ←z
             k ← increment by one
       end for
      end for
  for k=1 to L                        // length of image
             kx ← x(k)
             for i=1:n
               for j=1:n
                     if (i==n) && (j==n) && (w<=l)
                       if wmrk[w] ←0
            kx[I,j] ← kx[i,j]+35
          elseif wmrk[w] is 1
            kx[i,j] ← kx[i,j]-35
           end if
         end if
       end for
    end for
    w ← increment by 1
    x(k) ←kx
  end for
for j← 1to L step Z
       count ← increment by 1
      for i ←j to (j+63)
        data=data,x[i]
      end for
        embimg1[count] ←data
      data← reset to null
      end for
for i ←1 to Z
       dembimg ← [embimg;embimg1[i]]
      end for
 dembimg= blkproc dembimg in 8X8 blocks using 2-D
 inverse dct
```

2.2 Algorithm for DWT Symlet on Flat HDR

```
rgbImage ← read HDR image using              (7)
Watertm ← read image to be watermarked
 [h_LL,h_LH,h_HL,h_HH]  ←  apply  (4)  on
rgbImage
 Img ←h_LL /              *is now  new image*/
Get  Red,  Green  and  Blue  channels  and  get
single value decompostion
[w_LL,w_LH,w_HL,w_HH]  ←  apply  (4)  on
rgbImage
 img_watermark ← w_LL       /* new image */
Repeat 4 for img_watermark
On all the three channels apply
S_imgr1+(0.10*S_imgr2)     /*apply on all the
three channels */
watermarkimg ← U_imgr1*S_wimgr*V_imgr1'
watermarkimge ← concatenate all channels
Apply (5) on watermarking to get new image
result
```

EXTRACTION

```
Step1. [r c] ← get size of embedded image
Step2. for I ← 1 to r step Z
          for J ← 1 to c  step Z
            for ii ← I to I+7
               ctr ← increment by one
              for jj ← J to J+7
                 fdc ← increment by one
                 nz(ctr,fdc) ← m[iij,jj]
              end for
              ctr ←0
            endfor
            x(k) ←z
           k ← increment by one
          end for
       end for
Step3. while k < L
           for I ←1 to n
                    kx ← x(k)
                    dkx ← using 4 on 8X8 block
                    nn(k) ←dkx
                    wm1 ←[wm1 dkx(8,8)]
                    wmwd1 ←[wmwd1 kx(8,8)]
                    k ← increment by 1
             end for
           end while
Step4.     for I ← 1 to 32
                    for j ←1 to 32
                              diff ←wm(I,j)
 if diff greater than equal to 0 then
        wm(I,j) ←0
          elseif diff less than 0 then
              wm(I,j) ← 1
         end if
                    end for
           endfor
Step5. Display extracted image ← wm
```

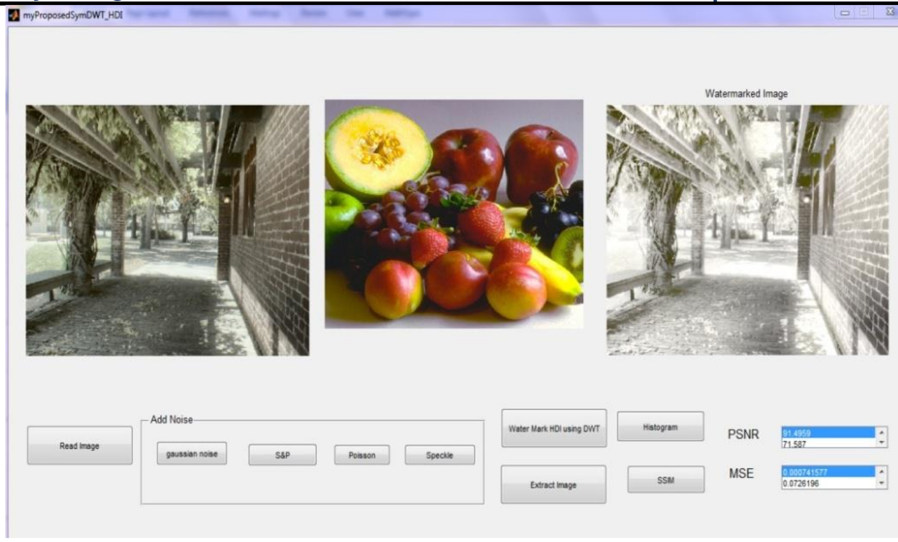


Figure 2.1shows the different performances of HAAR,DAUBECHIES and SYMLET12

Image & Size	**Colors**	**PSNR for Embedding Image**		
		HAAR	**DAUBECHIES 9**	**Proposed SYMLET 12**
Aisle1 (1,282KB)	**RED**	86.4311	87.6288	**91.4959**
	GREEN	69.9547	70.5873	**71.5870**
	BLUE	62.5964	64.2441	**64.4249**

Table2.1. Shows the results of HAAR, DAUBECHIES 9 and SYMLET 12 between original and Embedding Image of PSNR without any image processing Attack

Image & Size	**Colors**	**MSE for Embedding Image**		
		HAAR	**DAUBECHIES 9**	**Proposed SYMLET 12**
Aisle1 (1,282KB)	**RED**	0.0024	0.0018	**0.0007415**
	GREEN	0.1057	0.0914	**0.0726**
	BLUE	0.5756	0.3939	**0.3778**

Table2.2. Shows the results of HAAR, DAUBECHIES 9 and SYMLET 12 between original and Embedding Image of MSE without any image processing Attack

Image & Size	**Colors**	**PSNR for Extraction Image**		
		HAAR	**DAUBECHIES**	**Proposed SYMLET**
Aisle1 (1,282KB)	**RED**	69.9426	69.9236	**69.9489**
	GREEN	74.1363	74.0584	**74.9198**
	BLUE	73.9895	73.6495	**73.6891**

Table2.3.Shows the results of HAAR, DAUBECHIES 9 and SYMLET 12 between Embedding and Extracting Image of PSNR without any image processing Attack

Image & Size	Colors	MSE for Extraction Image		
		HAAR	DAUBECHIES	Proposed SYMLET
Aisle1 (1,282KB)	RED	0.1060	0.1065	**0.1066**
	GREEN	0.0404	0.0411	**0.0424**
	BLUE	0.0418	0.0452	**0.0448**

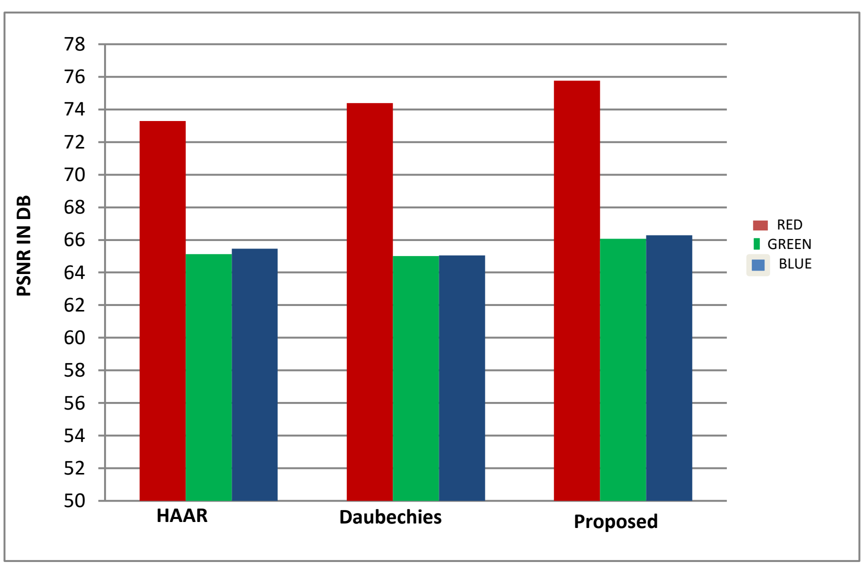
Table2.4.Shows the results of HAAR, DAUBECHIES 9 and SYMLET 12 between Embedding and Extracting Image of MSE without any image processing Attack

	Types of wavelet	NCR			
		Gaussian Noise	Salt & Pepper	Poisson	Speckle
Aisle1 (1,282KB)	HAAR	0.994557	0.99499	0.99671	0.99557
	DAUBECHIES	0.993107	0.99518	0.99673	0.99575
	PROPOSED SYMLET	0.998682	0.99845	0.99903	0.99877

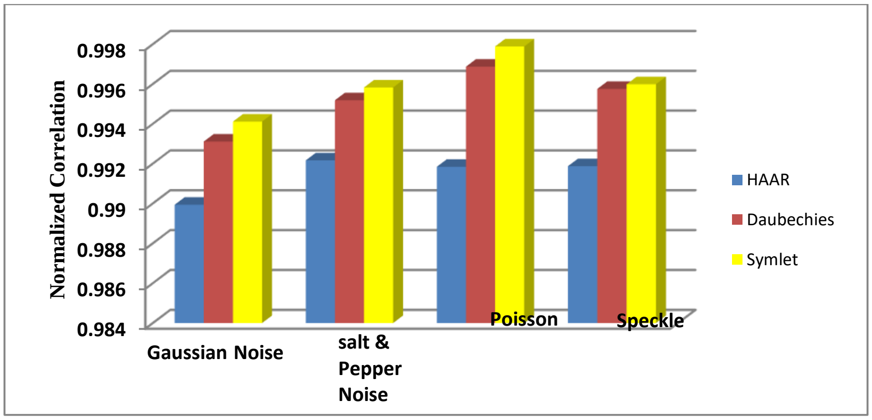
Table2.5. Shows Normalized Correlation Values of Extracted Watermarks against Different Attack

Image	Types of wavelet	SSIM			
		Gaussian Noise	Salt & Pepper	Poisson	Speckle
Aisle1 (1,282KB)	HAAR	0.991172	0.992133	0.99184	0.99187
	DAUBECHIES	0.989641	0.991903	0.99165	0.99166
	PROPOSED SYMLET	0.998682	0.998252	0.99903	0.99877

Table2.6.Shows Structural Similarity Index Values of Extracted Watermarks against Different Attack



Comparison of imperceptibility between Haar, Daubechies and Proposed Symlet



Comparison of noise attacks between Haar ,Daubechies and Proposed Symlet

3. Normalized Correlation

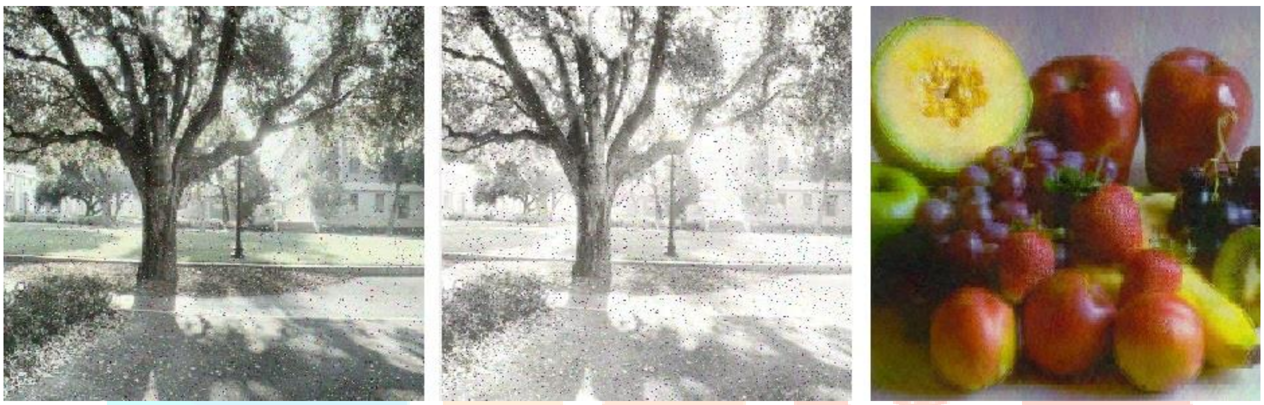
The correlation coefficient, a concept from statistics, is a measure of how well trends in the predicted values follow trends in past actual values. It is a measure of how well the predicted values, from a forecast model, "fit" with the real-life data. The correlation coefficient is a number between 0 and 1. If there is no relationship between the predicted values and the actual values, the correlation coefficient is 0 or very low. As the strength of the relationship between the predicted values and actual values increases, the value of correlation coefficient also increases. A perfect fit gives a coefficient of 1.0. Thus the higher value of correlation coefficient is better. It indicates the strength and direction of a linear relationship between two random variables.

To test the robustness of the proposed scheme, the watermarked image is tested against various image processing attacks like Gaussian noise (GN), Salt & Pepper (S&P),Poisson, Speckle and histogram equalisation (HE). Normalised cross-correlation (NC) is employed to evaluate the robustness of the algorithm. The Normal Correlation (NC) between the embedded watermark, W (i, j) and the extracted watermark W*(i, j) is given by,

$$NC = \frac{\sum_{i=1}^{Mw}\sum_{j=1}^{Nw}[W(i,j)].[W^{*}(i,j)]}{\sqrt{\sum_{i=1}^{Mw}\sum_{j=1}^{Nw}[W(i,j)]^{2}}\ \sqrt{\sum_{i=1}^{Mw}\sum_{j=1}^{Nw}[W^{*}(i,j)]^{2}}} \qquad (9)$$

Where, Mw and Nw denote the size of the watermark image. More the similarity between the extracted watermark and the original watermark more is the normal correlation value. Maximum value attained by normal correlation (NC) can be 1, resembling perfect matching of the extracted watermark with the original watermark image.

(a) (b) (c)



(d) (e) (f)

(g) (h) (i)

(j) (k) (l)

Figure3.1.HDR Images against various image processing attacks, HDR Watermarked Images against various image processing attacks and Extracted watermarked Images against various image processing attacks(a) HDR Image of Gaussian noise(GN ,0.02), (b)

watermarked HDR Image of Gaussian noise(GN ,0.02), (c) extracted Image of Gaussian noise(GN ,0.02),(d) HDR Image of salt &pepper noise(e)watermarked HDR Image of salt &pepper noise, (f)extracted Image of salt &pepper noise, (g) HDR Image of poisson, (h)watermarked HDR Image of poisson,(i)extracted Image of poisson,(j)HDR Image of speckle,(k)watermarked HDR Image of speckle, (l)extracted Image of speckle.

Conclusion

From Table 2.5 and 2.6 it is quite clear that Symlet DWT scores over Haar and Debauchies. DWT for Flat HDR images gives good result. But overall through the experiment the proposed technique gives the better result. In future the author intends to work on other wavelet forms using different tonemaps or no tonemap at all.

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