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Color image enhancement based on nonlinear filter and retinex algorithm

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Abstract. In this paper we suggested a new algorithm, to enhancement the contrast and lightness in the image. This algorithm depending on Nonlinear Filter (NF) depending on sigmoid function and Multi-Scale Retinex algorithm with Color Restoration (MSRCR) called NL- MSRCR , in this method two algorithms merge by using Yc_bc_r color space. NL- MSRCR algorithms compared with a New Nonlinear Adaptive Enhancement (NNAE), and Histogram Equalization (HE).Analysis results by comparisons these algorithms by used objective metrics as Entropy (E) and Lightness Order Error (LOE) and subjective criteria. The result of (NL- MSRCR) have a best result and better visual Comparing to the other algorithms.

Keywords: Image Enhancement, sigmoid function, lightness enhancement, Nonlinear Filter and Yc_bc_r color space

1.INTRODUCTION

Enhancing color image plays an important role in digital image processing. In many cases, images are taken in low light or irregular lighting. There is also a large difference between images taken in the camera and the scene in the real world. At present many algorithms have been proposed to enhance light and contrast in color images some of these algorithms are conventional a histogram equalization (HE), It is an easy and fast way to improve color images but it often causes errors in colors, especially in images taken from a few light situations (Gonzalez, et al., 2009). One of the most important methods found by NASA at the end of the nineties of the last century is MSRCR (Jabson, et al., 1997).

Retinex (Shuhang, et al., 2013) algorithm assumes that the sensations of color channel have a strong correlation with reflectance, and the visible light reaches to observers depends on the of reflectance and illumination (Li, et al., 2011). Most Retinex algorithms finding the reflectance as the enhanced result by removing the illumination, and therefore they can enhance the details in the image clearly. But it is impossible to exactly remove the illumination for the image of the not smooth depth. The center/surround methods depending on the local convolution of the lightness instead of the illumination without considering the limit of the reflectance. In fact, the reflectance should be within [0 or 1], which means the surface cannot reflect more light than that it receives. Moreover, it is unreasonable to simply remove the illumination which is essential to represent the ambience (Zhigang, et al., 2014). the defects of this algorithm is the halo effect. but Retinex algorithm often generates an Halle effect when improving the images. So many of the algorithms (Hazim, et al., 2016), (Jae, et al., 2012) and (Rahman, et al., 2004). that develop this method. It is presented to resolve the problem in parallel procedure for low or high intensity and poor contrast (LIPC or HIPC) images. The NNAE (Zhigang, et al., 2014)algorithm include three steps. First, a RGB color image is transform to an intensity image, then an adaptive intensity adjustment with local contrast enhancement is performed parallelly, by using a single scale shift-variant of Gaussian bilateral filter and then order Taylor series approximation technology, and finally colors are restored .it is have a good enhancement but the defect it is in time (have along time run). The rest of this work is designed to propose NL- MSRCR algorithm in details. While the Quality assessment is illustrated in section 3, and the experimental results on a series of the enhancement images are shown in Section 4 . The last part of this work is the conclusions are shown in.

2. proposed method

The suggested algorithm depending on lightness component in the MSRCR algorithm and Chromatic components in the nonlinear filter. This Processing is done using yc_bc_r color space

2.1 MSRCR algorithm

The retinex algorithm is a non-linear spatial/spectral Conversion that makes well enhancement in the local contrast and color constancy. This algorithm performs good in improving the contrast imagery typical of low-visibility conditions by using (Jabson, et al., 1997):

$$R_i(x,y,c) = \log[I_i(x,y)] - \log[F(x,y,c) \otimes I_i(x,y)] \tag{1}$$

Where $R_i(x,y,c)$ the output of component i (i $\in$ r,g,b) at position x,y , c is the Gaussian kernel k is finding by(Jabson, et al., 1997):

$$\iint F(x,y,c)\,dx\,dy = 1 \tag{2}$$

The MSR is a weighted summations of the outputs of many different SSR where (Jabson, et al., 1997), (Jabson, et al., 1996) :

$$R_{MSR}(x,y,w,c) = \sum_{n=1}^{N} W_n R_i(x,y,c_n) \tag{3}$$

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Where N is the number of scales, $R_i(x,y,c_n)$ the i'th components of the n'th scale, $R_{MSR}(x,y,W,c)$ the i'th spectral components of the MSR output and W_n the weight associated with the n'th scale. the a gain-offset is applied (Rahman, et al., 2004This can cause image colors to go towards gray, by (Jabson, et al., 1997):

$$R' = R_{MSR} \cdot I_i'(x,y,c) \tag{4}$$

Where I' given by

$$I_i'(x,y,a) = \log[1 + a \frac{I_i(x,y)}{\sum_{i=1}^{3} I_i(x,y)}] \tag{5}$$

In (Jabson, et al., 1997). a value of 125 is suggested for (a value). And the final stage is gain-offset by 0.35 and 056 respectively . In this paper we used *($w_1=w_2=w_3=1/3$)* and ($c_1=250, c_2=120, c_3=80$)

2.2 Nonlinear filter

The non Nonlinear filter depending sigmoid function algorithm This a algorithm it use to improve the optical quality of digital images captured under bad lightening conditions.

The first point of this algorithm is be made up of two part

A-is luminance estimation to obtain by conversion of the luminance information by below equation :

$$\mathrm{I} = 0.299\mathrm{r} + 0.587\mathrm{g} + 0.114g \tag{6}$$

And the normalize lightness is:

$$\mathrm{I_n} = I/255 \tag{7}$$

The second steep use the sigmoid equation as show below to enhancement The Illumination

$$\mathrm{I_{c_n}} = \frac{1}{[1 + \left(\frac{1-I_n}{I_n}\right)^{0.5}]} \tag{8}$$

This transform is illustrated in the figure(1) at low lightness condition we see the lightness increased were at high will decreased. The contrast enhancement , is, done by Center-surround contrast enhancement using:

$$\mathrm{R(x,y)} = \mathrm{I} \otimes \mathrm{F_i} \tag{9}$$

For many weighted value we used:

$$\mathrm{R_i} = \mathrm{W_i}\, \mathrm{S_i} \tag{10}$$

The contrast enhancement for each channel i is:

$$\mathrm{S_i} = 255\, (\mathrm{I_{c_n}})^{\mathrm{F_i}} \tag{11}$$

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$$F_i = \frac{R_i}{I} \tag{12}$$

Where $i = 1,2,3$ represents for the (red ,green, blue) components W_i is the weight factor for each constant enhancement .

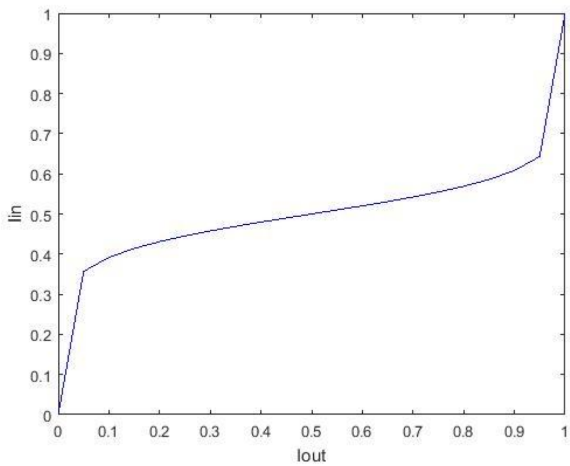

Figure 1: Relationship between input lightness versus output lightness based on sigmoid function

Color restoration a linear color restoration process is applied, it is based on the chromatic information of the original image it is applied to convert the enhanced intensity image to RGB color image .The (r_e, g_e, b_e) of the restored color image are obtained by:

$$C_e(x, y, i) = C(x, y, i)R_i \tag{13}$$

Where

$$r_e = \frac{R}{I}r, b_e = \frac{R}{I}b, g_e = \frac{R}{I}g, \tag{14}$$

where w1=w2=w3=1/3. The steps of the NLfilter is:

1. Input color image $c(x, y)$.
2 estimating lightness $I(x, y)$.
3. Normalize the lightness component $I_n(x, y) = I(x, y)/255$.
4. finding transform the sigmoid function $I_{C_n} = \frac{1}{[1+\left(\frac{1-I_n}{I_n}\right)^{0.5}]}$
5. Compute reflectance component from $S_i = 255\,(I_{C_n})^{F_i}$

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6. *The enhanced image result from ;*
$r_E = \frac{R}{I} r, b_E = \frac{R}{I} b, g_E = \frac{R}{I} g,$

2.3 NL-MCRCR algorithm

This algorithm includes NL filter and MCRCR algorithm based on yc_bc_r color space(Marc , 1997). The chromatic components are result from c_bc_r , and the lightness component calculate from y component ,then used invers transform to find enhanced image the flowchart in the figure (2) shows these algorithm.

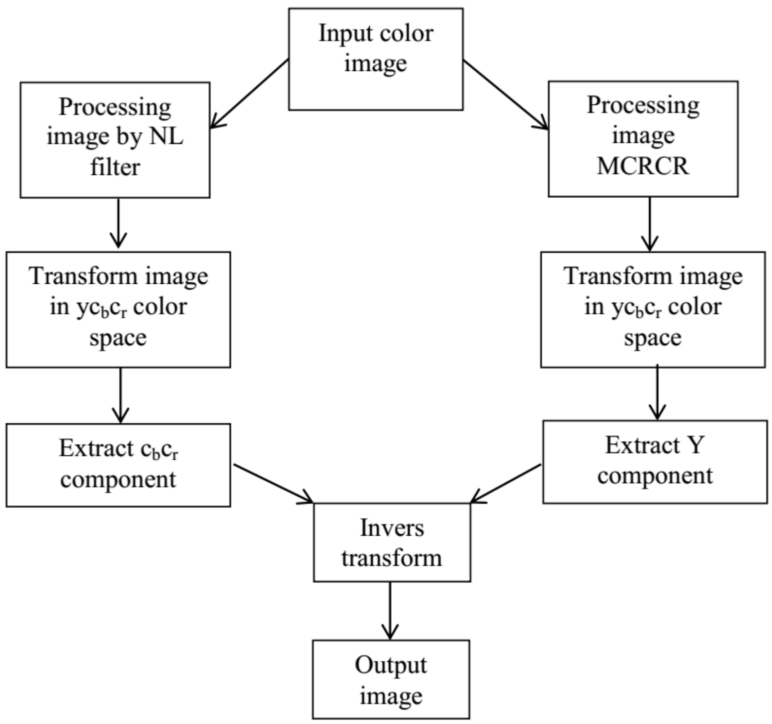

Figure 2: Flowchart of NL-MCRCR algorithm.

3. Quality assessment

There are a lot of non-reference measures to measure the quality of color images, most importantly Entropy (E) and Lightness Order Error (LOE)**:**

3.1-**Entropy**

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Entropy is used to measure the quality of images, its great value indicates an increase in quality, whereas when the value of entropy decreases, it indicates a decrease in quality. Antropyi can be applied to probability density function at intensity level p(I) when measuring the quality of color images given in relation (Gonzalez, et al., 2009):

$$E\ (I) = -\sum_{i=0}^{l-1} p(I)\ log p(I) \tag{15}$$

Where I is total number of gray level.

3.2. Lightness Order Error

Its measure is the lightness order error (Shuhang, et al., 2013). between the original image *I* and its process image *I*p. The lightness *L(x, y)* of an image is given as the maximum of its three color channels:

$$L(x, y) = \max_{c\in\{RGB\}} I^c(x, y) \tag{16}$$

The relative order difference of the lightness is given by:

$$RDiff = \sum_{i=1}^{m} \sum_{j=1}^{n} (M(L(x, y), L(i, j)) \oplus M(L_p\ (x, y), L_p(i, j)) \tag{17}$$

$$M(x, y) = \begin{cases} 1 & for\ x \geq y \\ 0 & else \end{cases} \tag{18}$$

m and *n* being the height and the width, *M(x, y)* is the unit step function, $\oplus$ is the exclusive-or operator. The LOE metric is given by:

$$LOE = \frac{1}{m*n} \sum_{i=1}^{m} \sum_{j=1}^{n} RDiff\ (i, j) \tag{19}$$

4. Results and Discussions

In this study, color images with poor lighting were improved. The MATLAB program was used in the process. Several images were selected in size as shown in Fig3 (in 1a and 2a) and Fig4(3a and 4a), with size 1200×900, 1200×680, 1200×794 and 688×510 respectively ,all images with type JPG. Fig3 and in Fig4 represents enhanced images using algorithms and its histogram. From the subjective measure we observe the best method is NL-MSRCR followed by MSRCR. From this figure for the histogram we observe an expansion in histogram values when enhancement, for enhanced images in MSRCR algorithm, the histogram is more fluctuate, resulting in noise. While the holograms for enhanced images in the suggested algorithm have little fluctuation. The table 1 represents the values of the quality scale for the Entropy and LOE of all enhanced images, For the Entropy scale, and the best method is NL-MCRCR algorithm often followed NNAE, Where the values were greatest. When using a LOE scale we note that the best algorithm is HE then NNAE. When a small values for LOE for enhanced images do not necessarily enhance lighting. When the original value is enhanced, the value of the meter is large.

5. Conclusions

In this study, color images were enhanced using an algorithm based on non-linear filter and retinex algorithm. By objective metrics as Entropy and LOE , and subjective metrics. We can see the proposed

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method has succeeded in enhancing the lightness and contrast in low lightness images or irregular lighting images when compared with other algorithms like NNAE , MSRCR and HE .

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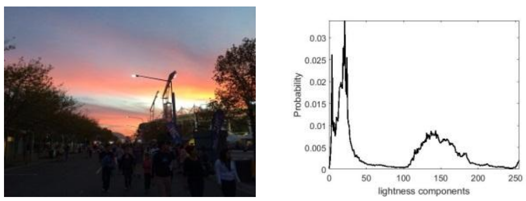
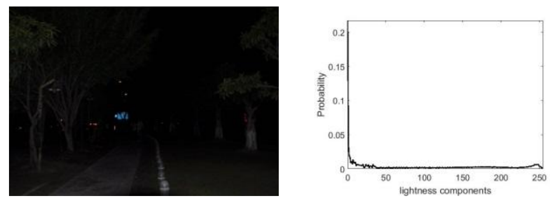
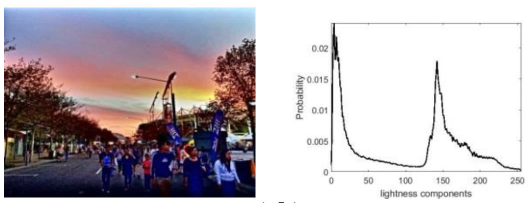


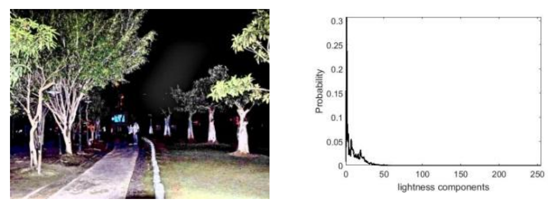
(1a)



(2a)



(1b)



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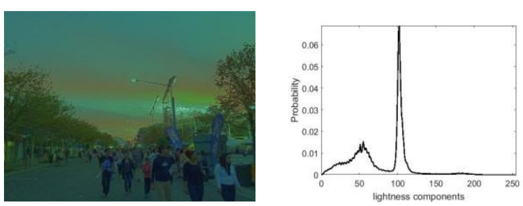
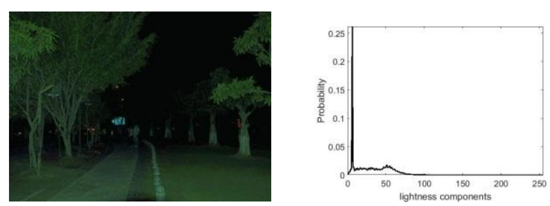


(1c)



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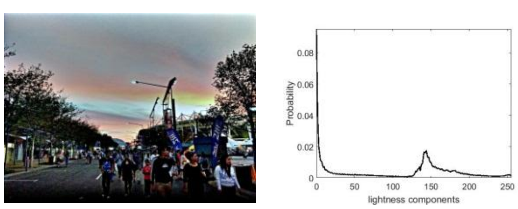

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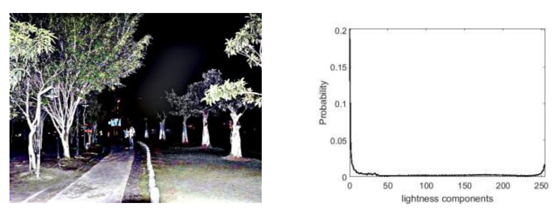

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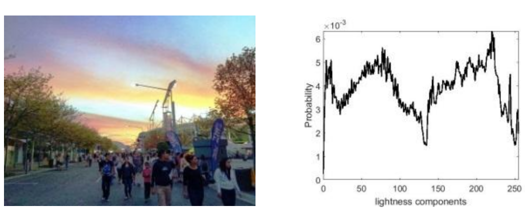
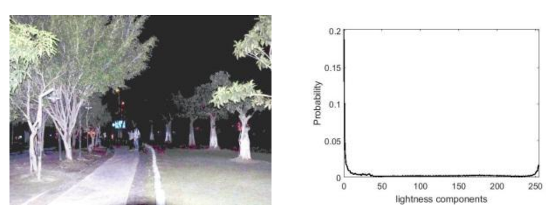


(1f)



(2f)

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Figure (3): First column represents the first enhance image and the second column represents the histogram of the first image. The third column represents the second enhanced image, and the fourth column represents the histogram for those images. Symbols (a) refers to the original images , (b) enhanced image by NL-MSRCR , (c) enhanced image by NNAE, (d) enhanced image by MSRCR and (f) enhanced image by HE.

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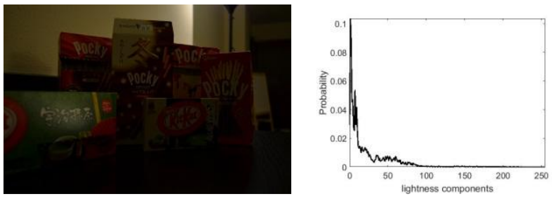
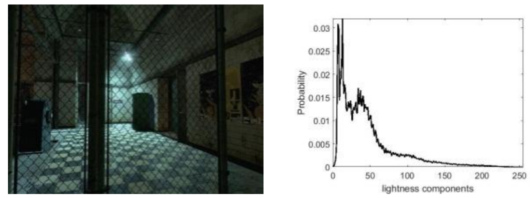
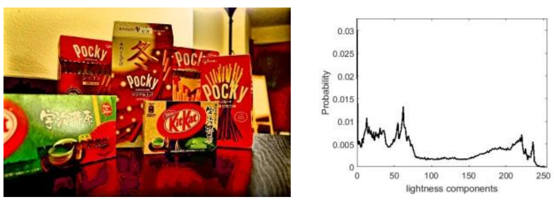


(3a)



(4a)



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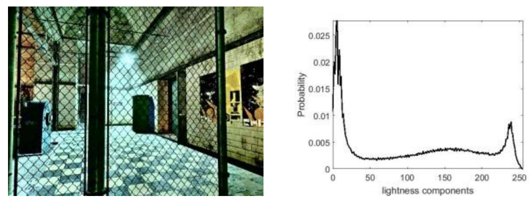

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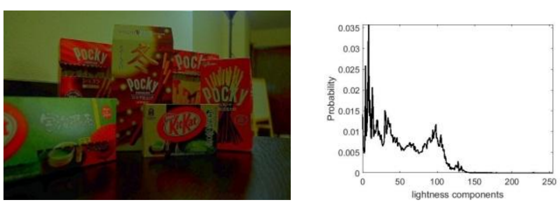

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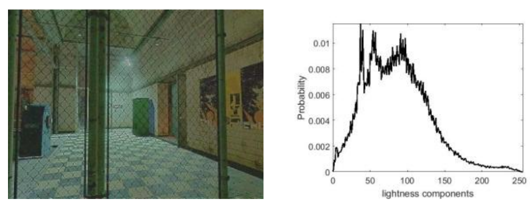

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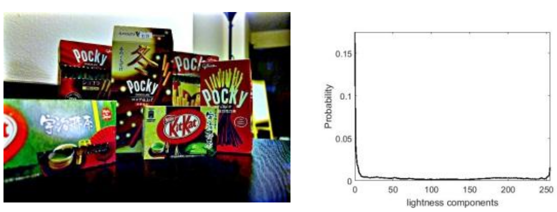

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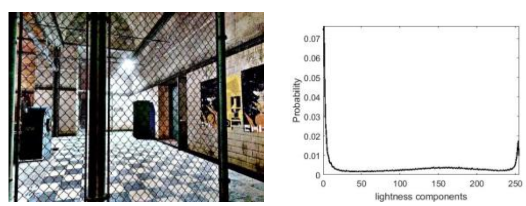

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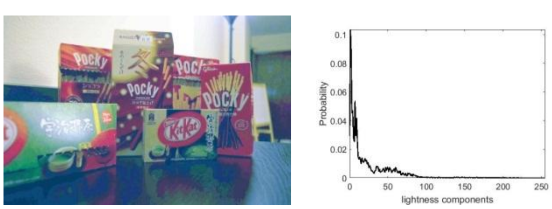

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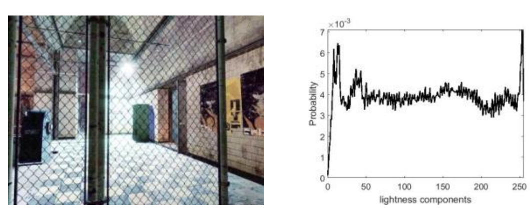

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Figure (4): First column represents the third enhance image and the second column represents the histogram of the first image. The third column represents the fourth enhanced image, and the fourth column represents the histogram for those images. Symbols (a) refers to the original images , (b) enhanced image by NL-MSRCR , (c) enhanced image by NNAE, (d) enhanced image by MSRCR and (f) enhanced image by HE.

Table 1: Quality-measurable values Entropy and LOE for enhanced images using different algorithms.

	Image 1			Image 2	
Method	LOE	Entropy	Method	LOE	Entropy
NL- MSRCR	35841.42	7.081812	NL- MSRCR	10516.11	6.06134
NNAE	30325.84	7.114419	NNAE	22285.7	5.743861
MSRCR	42562.37	6.236128	MSRCR	29221.99	5.79673
HE	25137.9	5.971253	HE	10954.44	4.529517
	Image 3			Image 4	
Method	LOE	Entropy	Method	LOE	Entropy
NL- MSRCR	18406.78	6.23642	NL- MSRCR	21028.19	6.884789
NNAE	19856.38	6.155014	NNAE	17016.25	7.391223
MSRCR	25039.03	5.129581	MSRCR	21312.82	6.038356
HE	5966.102	5.22352	HE	13997.71	5.941678

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