Color Image Modification with & without Hue Preservation

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Abstract – Color image modification is an essential component for several applications and the grayscale transformation is generally mapped to the color image indirectly. Although several techniques have been used for this transfer, they suffer from gamut mapping issue. In this paper, it is aimed to map the transformation in an accurate manner while preserving hue. Modifying the image in different color space than the original retains hue to a promising extent, but suffers from the gamut problem. A generic scheme to map grayscale changes to the color space for all kinds of spatial modification is proposed here. The hue preserving color image enhancement (HPCE) scheme discussed here is free of gamut-mapping issue and shows promising results in transferring the grayscale transformation to the color image in a simplistic manner. The proposed HPCE scheme is analysed qualitatively through visual appearance and quantitatively using color difference metrics SHAME and CID, gray image difference and EBCM measures. Different gray scale transformations such as S-type enhancement and different forms of histogram equalization techniques are applied on Berkeley dataset of 500 images to prove the efficacy of proposed algorithm.

Keywords: Color image modification, hue preservation, histogram equalisation, color difference metric, image enhancement

1. Introduction

Color images being three-dimensional require relatively larger memory space and computing resources for processing three different channels in an image. It is thus preferred by the users to develop image-processing schemes on grayscale image and transfer modifications to the color scale accordingly. Among several modifications, image enhancement is the process of applying a non-linear transformation to the image for a specific application [1]. The image enhancement techniques, generally developed for grayscale images, are later transferred to the RGB space. These transformations from one space to the other lead to a gamut-mapping problem, wherein the values of the modified pixels do not lie within their specified ranges. As a result, the chromaticity content of the original image is not modified accordingly as depicted in Fig 1.

(a) (b)

Figure 1 Original image at left and modified hue distorted image on the right

The most prevalent technique for enhancing color images is to convert the image in original RGB space to the HSV color space, and apply the transformation on the luminance scale alone while keeping the hue and saturation matrices constant [2]. This modified image is then converted from the HSV space to the RGB color space by applying an inverse transformation. However, this technique suffers from the problem of hue inconsistency between the original and modified image, owing to the out of bound gamut mapping from one color space to the other [3]. Some of the other technique targets on applying the transformation on all the three R, G, and B matrices separately, resulting in a completely distorted image as the correlation between different color channels is not considered. Another technique applies the transformation on the luminance scale and multiplies a factor of change on the hue and saturation matrices correspondingly [1].

In one of the approaches, a 3D color histogram equalization is utilized which aims at uniform probability distribution of color components [4]. Menotti et al. defined the histogram of a color image as the product of cumulative distribution function (CDF) of each color channel which is processed to yield enhanced color image [5]. Menotti et al. further employed 1D and 2D histogram to estimate 3D histogram, which is equalized to yield enhanced color image [6]. Mlsna and Rodriguez [7] introduced a histogram explosion method, which aims to exploit the full 3-D RGB gamut. This algorithm selects an operating point preferably on the diagonal of the RGB cube to prevent hue changes and expands the color space of an image by equalizing the 1-D histogram. Although these schemes avoid color space conversions and gamut problem, they lead to changes in image brightness levels [8].

In [9], Cherifi et al. proposed a method in which the contrast of each sub-band is enhanced using a nonlinear mapping function, wherein the RGB color image is obtained from the enhanced luminance along with the original chrominance components. Hee et al. [10] proposed a 3-D color histogram equalization method that produces a uniform distribution in grayscale histogram by defining a new cumulative probability density function in a 3-D color space. Hanmandlu et al. [11] presented a technique in which the saturation component was made variable along with the luminance component while keeping the hue of the image fixed to enhance the color image. In this technique, two separate power law transformations are used for both the luminance and saturation components. Sahani et al. equalizes all the color channels independently and incorporate reference image information to guide target color image [12]. In Pitas and Kiniklis method [13], the histogram equalization is performed only on the luminance and saturation channels. However, it has been reported that the modification of the saturation channel may result in unnatural images [14].

The other set of approaches transfers image from RGB to different color spaces such as LHS, HIS, YIQ, etc. The selection of color space for transformation is a fundamental issue in color image enhancement techniques which vary from classical RGB to HSV, CIELAB, LUV, and others. An HSV-based color image enhancement using multi-scale analysis has been developed by Huang et al [15]. Xianghong et al. [16] proposed an image enhancement scheme based on wavelet analysis for color medical image application. These methods share a point in common, that is, the contrast enhancement is applied in an alternative color space instead of the original RGB space, and the enhanced image is obtained by the inverse transformation of the modified coefficients [9]. Song et al. proposed color histogram equalization that improves image saturation by matching ratio between modified and original color image channels [17]. However, in an attempt to maintain the hue and saturation simultaneously, the expected transformation is not mapped correctly to the color image. Lin et al. proposed color image enhancement in an optimization framework so as to improve the image contrast while maintaining the mean image brightness level same as that of the original image. This scheme is a collection of different sub-schemes that do not require histogram clipping and sub-image equalization separately [18]. Some of the researchers have also proposed to use evolutionary optimization algorithm such as genetic algorithm, particle swarm optimization for enhancing color images by tuning enhancement parameters as per image content [19-21].

Naik and Murthy proposed a framework which enables a class of grayscale image enhancement techniques to be mapped to the color images [3]. The enhancement is applied to the luminance scale of the color image, and a hue-preserving transformation is then used to find the modified color values. However, it has an inherent disadvantage of being applicable to a particular class of image enhancement techniques alone, that is, to the ones whose enhancement function is defined by a 2D non-linear equation and not generically applicable for all piece-wise 2D transformations. In this paper, a refinement to the hue-preserving algorithm by Naik and Murthy is proposed by formulating a scheme that does not require the transformation to be specified by a non-linear equation and is instead generic in nature.

This paper is organised as follows: section 2 presents a brief mathematical background on color image enhancement, while section 3 enlists the modification proposed for improved hue preservation. Section 4 provides an evaluation of the proposed methodologies compared to state-of-the-art techniques and finally, section 5 concludes the paper.

2. Brief background

Histogram equalization (HE) is one of the simplest techniques for contrast improvement, which obtains its transformation function from the CDF of the input image. HE obtains a mapping function to modify the original image to be as close as possible to the uniform distribution. Let us consider an image $I = I(i,j) | 1 \leq i \leq M, 1 \leq j \leq N\}$, of size $M \times N$, where $I(i,j) \in \mathbb{R}$. The probability density function (PDF) of the image is given by:

$$p(k) = n_k / n_T, \quad \text{for } k = 0, 1, \dots, \mathrm{L} - 1 \tag{1}$$

Here n_k is the number of pixels with intensity k, L is the maximum intensity value of an image, n_T denotes the total number of pixels in the image, and $p(k)$ is the probability of an intensity value in an image. The CDF, $c(k,)$ is given by:

$$c(k) = \sum_{i=0}^{k} p(i) \tag{2}$$

The transformation function $T(k)$ for HE is obtained by multiplying $c(k)$ with the maximum intensity level of the output image. For a b-bit image, there are $2^b = L$ intensity levels and the transformation function is given by:

$$T(k) = \lfloor (L-1)c(k) + 0.5 \rfloor \tag{3}$$

where $\lfloor \quad \rfloor$ denotes the floor operation. The modified grayscale image is obtained by using this transformation mapping to fit the criteria of uniform distribution. The grayscale modifications are then mapped to the RGB color space using an appropriate transformation scheme as developed by the user. However, owing to their certain limitations, researchers have tried to put up several techniques [22] such as: separate equalization of the three color components, 3D Equalization in the RGB space, equalization of the intensity component in the HSI space, 2D Equalization for intensity and saturation in the HSI space, etc.

Most of the color image enhancement schemes require the transformation mapping function to be developed for grayscale. It is then translated to the color scale by the inverse transformation of enhanced coefficients [23,2,24-29] by either keeping the hue and saturation matrix constant or by applying a scale factor to either or both of them. This is not always hue-preserving and often leads to an added color distortion in the image [3]. To solve this issue, Naik and Murthy [3] proposed a methodology which is based on the fact that shifting and scaling operations in any color space is hue preserving [30,31]. In order to achieve a hue preserving transformation, the linear changes for all three vectors should be same and is given as:

$$x^{k'} = \alpha(x^k) * x^k + \beta. \tag{4}$$

x^k is the original grayscale value, α and β being the scaling and shifting parameters respectively, and $x^{k'}$ is the modified grayscale value.

3. Proposed methodology

In this paper, a hue preserving color image enhancement (HPCE) scheme is proposed which aims at direct mapping of gray scale transformation to the color scale. Given an input color image

I, the luminance scale is represented by $I_L(i, j)$, *R* channel by $R(i, j) = I(i, j, 1)$; *G* channel by $G(i, j) = I(i, j, 2)$; *B* channel by $B(i, j) = I(i, j, 3)$, and the modified grayscale image after enhancement by $I_E(i, j)$.

In this method, an alpha matrix is computed for the complete image rather than finding the alpha value corresponding to each intensity level through a non-linear transformation function as done in Naik and Murthy's algorithm. This small refinement provides robustness and adaptability to the algorithm for different modifications. In this framework, we propose a generic methodology for transferring the gray-scale modifications to the color image irrespective of the kind of alteration done on the original image (linear, non-linear or piecewise linear). The alpha value is computed as the ratio of modified image to the original image in grayscale, as compared to Naik and Murthy's method which computes alpha value by mapping the non-linear transformation to a combined RGB scale. The complete methodology for HPCE is described below as follows:

1. Calculate alpha (α) as

$$\alpha(i,j) = I_E(i,j)/I_L(i,j) \tag{5}$$

where I_E is the modified grayscale image, I_L is the original grayscale image, and i and j are the pixel positions in the images. The transformation of I_L to I_E is represented through the transformation function $T_{i,j}(x)$ as:

$$T_{i,j}(x) = \begin{cases} \delta_1 + (m - \delta_1)\left(\frac{x-\delta_1}{m-\delta_1}\right)^n, & \delta_1 \le x \le m \\ \delta_2 - (\delta_2 - m)\left(\frac{\delta_2-x}{\delta_2-m}\right)^n, & m \le x \le \delta_2 \end{cases} \tag{6}$$

2. Here, *T* denotes an S-type enhancement function such that $x, T(x) \in [\delta_1, \delta_2]$, where $\delta_1 = 0$, and $\delta_2 = 255$. It acts as a standard contrast enhancement function with n = 2, and m = 0.5. Find positions for alpha when it is less than or equal to '1' and store it in a local variable *L1*.
3. Similarly, find positions for alpha when it is greater than '1' and store it in another local variable *L2*. The pixels for which alpha is greater than '1' will exceed the gamut of RGB space on applying the transformation and is thus taken to CMY color space and processed as explained in steps 5-9 below.
4. The values stored in location *L1* are used to transform all the three scales of *R*, *G*, and *B* by the transformation equation given as

$$R_{mod}(i,j) = \alpha(i,j) * R(i,j) | (i,j) \in L1 \tag{7}$$

Use similar equation for both *G* and *B* channels, transforming only those pixels where 'α' is less than '1'.

5. The image locations at *L2* is converted to CMY scale as depicted in eq. (8) – (10)

$$C(i,j) = 255 - R(i,j)|(i,j) \in L2, \tag{8}$$

$$M(i,j) = 255 - G(i,j)|(i,j) \in L2, \tag{9}$$

$$Y(i,j) = 255 - B(i,j)|(i,j) \in L2. \tag{10}$$

This step transforms the color vector from RGB to CMY space in which the transformation is mapped to solve gamut problem. Following this step, the implementation is shown for the *R* channel alone. *G* and *B* channels will have a similar realization.

6. Determine, $$v1(i,j) = 255 - I_L(i,j)|(i,j) \in L2 \tag{11}$$

$$v2(i,j) = 255 - I_E(i,j)|(i,j) \in L2. \tag{12}$$

7. Calculate $\alpha_{mod}(i,j) = v2(i,j)/v1(i,j)$.

α_{mod} provides the spatial ratio between modified and the original image in CMY space and is used for modifying indices where α value is greater than 1. It is then followed by propagating this change to other scales in a controlled and distributed manner and is done by the following steps.

8. Compute $C_{mod}(i,j) = \alpha_{mod}(i,j) * C(i,j)$ to provide the modified values in CMY space.
9. And, $R_{mod}(i,j) = 255 - C_{mod}|(i,j) \in L2$ is obtained for all those locations where alpha is greater than one.
10. Steps 8 and 9 is replicated for modifications in *G* and *B* channels. The modified intensity values obtained for *R*, *G* and *B* channel is a strong reflection of controlled change for the enhancement process considered here. After obtaining transformations as explained above for all the three channels, hue preserved modified image channels is given as, $I(i,j,1) = R_{mod}(i,j)$, $I(i,\ j,2) = G_{mod}(i,\ j)$, and $I(i,\ j,\ 3) = B_{mod}(i,\ j)$.

The proposed algorithm described above is inspired from the works of Naik and Murthy (NM) and resembles very closely to it. The two main differences between this technique and NM algorithm are that the NM algorithm requires to compute α values for each intensity levels whereas the proposed scheme in this paper finds α for the complete image at one go represented using eq. (5). Secondly, the proposed scheme does not require the gray scale transformation to be represented through a mathematical formula and can instead use the modified gray scale values directly. And, thirdly the NM algorithm adds up the intensity values for all the channels together for computing alpha value which is not the case with the proposed scheme. These changes not only leads to faster transformation but also an improved color mapping.

A typical non-hue preserving color image enhancement scheme (NHPCE) can be depicted as a process in which the transformation function obtained for grayscale is mapped to the R, G and B color scales separately. For a given transformation function in the grayscale, the mapping function for each of the R, G, and B scales are same and no hue preservation scheme is applied here. For a transformation function $T_{i,j}$ the mapping functions are given as:

$$R_{mod}(i,j) = T_{i,j}(R)|(i,j) \in I_L,$$
$$G_{mod}(i,j) = T_{i,j}(G)|(i,j) \in I_L,$$
$$B_{mod}(i,j) = T_{i,j}(B)|(i,j) \in I_L \ . \tag{11}$$

This transformation function, T is same as the previous S-type enhancement function defined in eq. 6. The NHPCE scheme explained here for the purpose of comparisons in analysis section.

4. Evaluation methods

The HPCE algorithm developed here is compared with other techniques used for transferring modification in grayscale to the color image. The images selected for testing are specifically chosen so that they have a good mix of different color tones. In order to depict the ability of HPCE scheme, S-type enhancement function as used by Naik and Murthy (NM) is implemented and transferred to the color scales. Along with NM's scheme, the chroma constant (CC) and NHPCE methodology is also implemented for comparing the grayscale transformation to color scale. The chroma constant (CC) scheme converts the color image from RGB to HSI color space and applies the transformation on intensity component alone while maintaining hue and saturation matrices constant.

In this paper, visual investigation and objective evaluations are carried out to analyse the performance of HPCE scheme as compared to other gray to color transformation schemes. The objective evaluation incorporate different color difference metrics, which computes the color dissimilarity between the two images. The mean absolute difference between gray scale images abbreviated as GID is used here to compare enhanced grayscale image (I_E) and the grayscale image obtained from modified color images $\hat{I}_E = (R_{mod} + G_{mod} + B_{mod})/3$. The difference in Edge-Based Contrast Measure (EBCM) [32] is also computed for the enhanced grayscale image I_E and the grayscale image obtained from modified color images $\hat{I}_E$. EBCM is one of the reliable indicators of transformation in an image that measures the contrast information from edges. An image that undergoes expected transformation will have lower difference in EBCM value and is indicative of the true mapping to the color scale image here. The chromaticity difference measures are those quantitative measures that are used for determining the difference between two color images. Among the available color difference metrics, the spatial hue angle metric (SHAME) [33], and color image difference (CID) [34] metric is used here for computing the difference in hue between the original and modified image directly.

The Spatial Hue Angle Metric (SHAME) technique is a spatial extension of the hue angle metric [35] to account for human visual system. It uses the same basic framework as S-CIELAB [36] where images are spatially filtered before applying the difference equation. This metric is based on the hue histograms of the image and changes to the dominant hues of the image are weighted higher than the non-dominant ones. SHAME has shown to correlate well with perceived color image difference [37]. Color Image Difference (CID), a metric proposed by Preiss and Urban, is an extension of structural similarity index measure (SSIM) [38] for color images. It incorporates five terms, i.e. local lightness, chroma, hue, local lightness contrast and lightness structure differences for predicting the difference between two images. This metric is suitable since it directly calculates the difference in hue between original and its reproduction. A higher value of both CID and SHAME indicate larger difference in hue. These metrics calculate the perceived image difference between original and modified image.

5. Results & Discussions

The HPCE algorithm proposed here is analysed by applying different enhancement functions on different gray scale images and mapping it to the original color image. The objective evaluation is carried out using different metrics such as GID, EBCM, SHAME, and CID for 500 Berkeley image dataset of which the cumulative results are tabulated in following subsections.

5.1 Visual investigation

Visual investigation of images processed using HPCE scheme is provided here for a specific set of images and a qualitative discussion is put forth. Figures 2, 4-6 shows test images modified by different kinds of enhancement techniques. Fig 2 shows the test image *baboon* modified by S-type enhancement and is analysed for hue consistency and transformation mapping from grayscale to color scale by different Color Image Modification (CIM) algorithms. The chromaticity content of images modified by NM and HPCE is nearly similar, but slightly different from the original image. The image modified by NHPCE has a much larger brightness level than the original image and the tone of the image varies greatly as compared to the original. Fig 3 shows the hue channel of the LCH color space visualized with a color map where the false color indicates the different hues. We can see that the NHPCE modified baboon image has a shift in the hue. It thus becomes necessary to have a methodology that preserves the hue of the image while mapping transformation from gray to color image simultaneously.

Fig. 2 (f) shows the original enhanced grayscale image, and Fig. 2 (g-j) shows the grayscale images obtained from the modified color image. As seen, Fig. 2 (i) seems to be the closest replica of the original enhanced grayscale image indicating true mapping of the transformation to the color image. Fig. 2 (g) is also found to have a similar grayscale image after modification but is slightly darker than the original grayscale image.

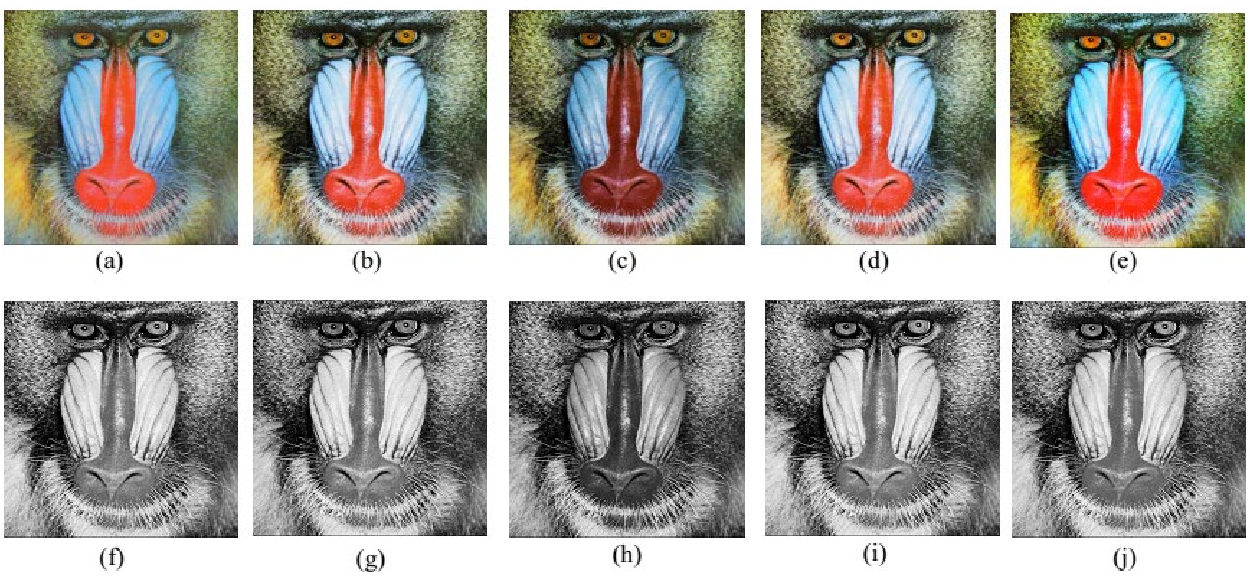

Figure 2 Test image *Baboon* modified by S-type enhancement color images: (a) Original, (b) NM, c) CC, d) HPCE, e) NHPCE; Grayscale images: f) Original enhanced image, g) NM, h) CC, i) HPCE, j) NHPCE

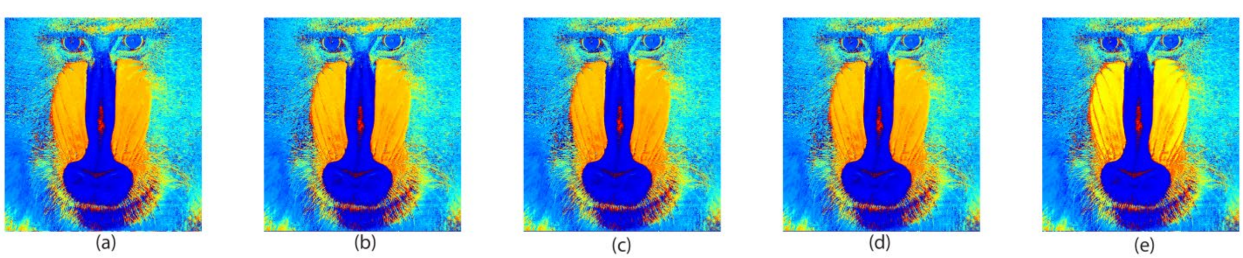

Figure 3 Visualization of hue angles from the LCH color space for a) Original (b) NM, c) CC, d) HPCE, e) NHPCE.

In Fig. 3, one can notice that the NM, CC, HPCE modified images in LCH color space has similar visualization as compared to the original. However, the NHPCE modified image has a relatively larger shift in hue at the nose region of baboon indicated with a relatively larger tinge of blue and yellow color. Different image enhancement techniques other than the S-type enhancement, like Weighted Threshold Histogram Equalization (WTHE) [39], Non-Parametric Histogram Equalization (NMHE), [40] and Histogram equalization (HE) has been applied on separate images and analysed for visual investigation below. Fig. 4 shows test image *cap* enhanced by WTHE scheme. The transformation mapping by NM technique shown in Fig. 4 (b) is found to preserve hue to a better extent as compared to the HPCE Fig. 4 (d). However, it has a larger difference in grayscale image obtained by converting the NM modified color image to gray scale as shown in Fig. 4 (g) as compared to Fig. 4 (f). Fig. 4(i) is seen to perform well at this index thus depicting more confidence in transferring modification from gray scale to color image as compared to the other schemes. The color and grayscale image modified by NHPCE is shown in Fig. 4 (e) and Fig. 4 (j), respectively. The color image is found to have relatively large hue content as compared to the original while the grayscale image is approximately similar to the original enhanced image Fig. 4 (f). It is thus essential to mention here that both the gray scale and color image should be a true reflection of the modification being targeted to the color image. Hue preservation does not necessarily mean that the hue of the original and modified image should be same, but instead it should be such that the conversion of modified color image to grayscale should be as close as possible to the image enhanced in grayscale.

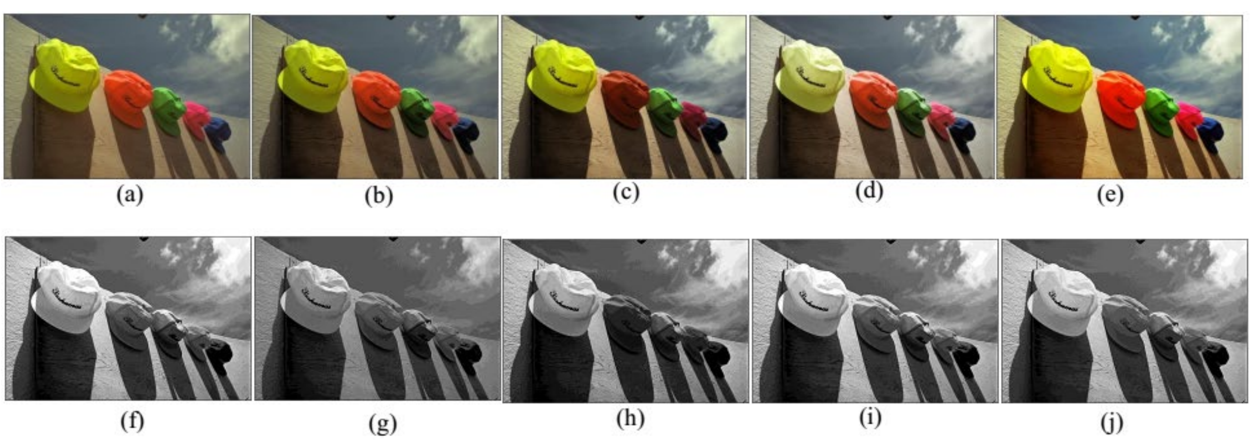

Figure 4 Test image *Cap* modified by WTHE (a) Original image, Results obtained for S-type enhancement on grayscale and transformed in color scale by (b) NM, c) CC, d) HPCE, e) NHPCE & Grayscale images for f) Original enhanced image, g) NM, h) CC, i) HPCE, j) NHPCE.

Fig. 5 and Fig. 6 show test image *Birds* and *Fruits* modified by NMHE and HE, respectively. The observations for these two figures are also similar to above. Fig. 5 (e) and Fig. 6 (e) is seen to have relative large brightness changes as compared to the original. The grayscale image is also presented here to depict the performance of these color image modification algorithms.

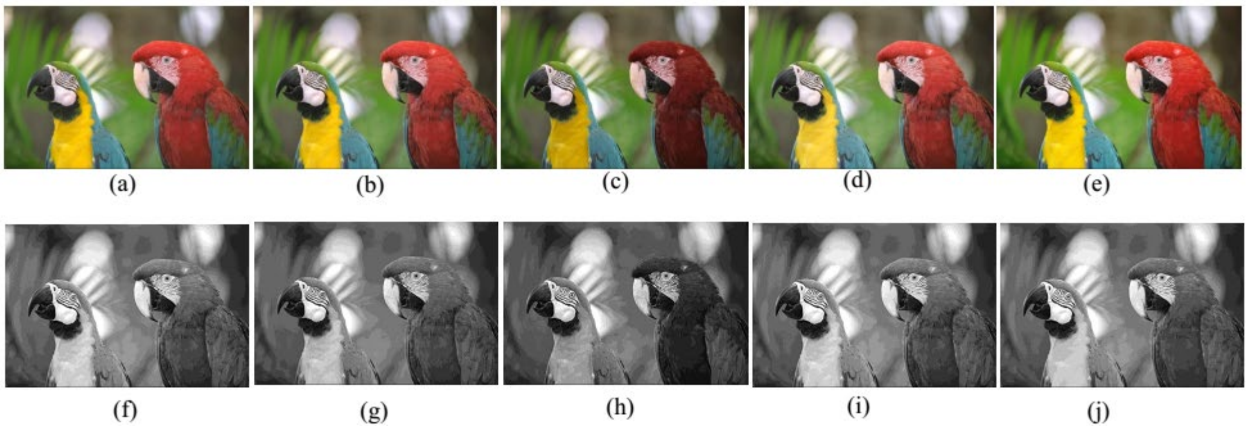

Figure 5 Test image *Birds* modified by WTHE (a) Original image, Results obtained for S-type enhancement on grayscale and transformed in color scale by (b) NM, c) CC, d) HPCE, e) NHPCE & Grayscale images for f) Original enhanced image, g) NM, h) CC, i) HPCE j) NHPCE

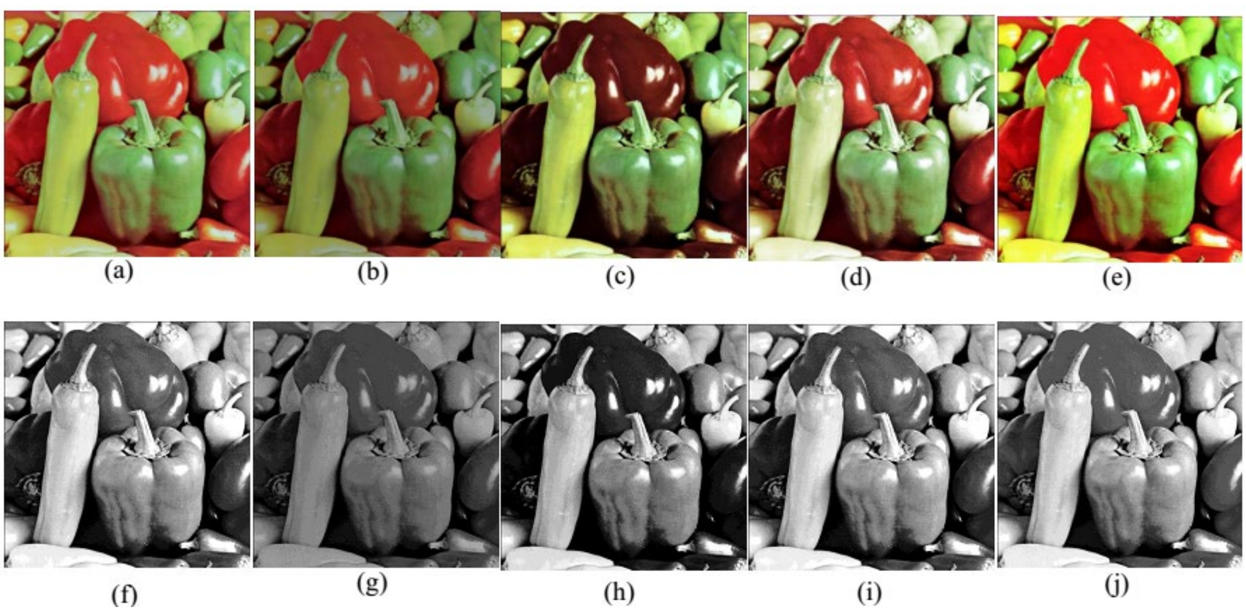

Figure 6 Test image *Fruits* modified by WTHE (a) Original image, Results obtained for S-type enhancement on grayscale and transformed in color scale by (b) NM, c) CC, d) HPCE, e) NHPCE & Grayscale images for f) Original enhanced image, g) NM, h) CC, i) HPCE j) NHPCE

Four different images are further experimented comprising of two images widely used in image processing techniques, *Lady* and *window*, and two other image from Berkeley dataset. An S-type enhancement modification is applied on grayscale and mapped using NM, CC, HPCE and NHPCE scheme as shown in Fig. 7 – 10.

Figure 7 Test image *Lady:* (a) Original image, Results obtained for S-type enhancement on grayscale and mapped to color scale by (b) NM, c) CC, d) HPCE, e) NHPCE

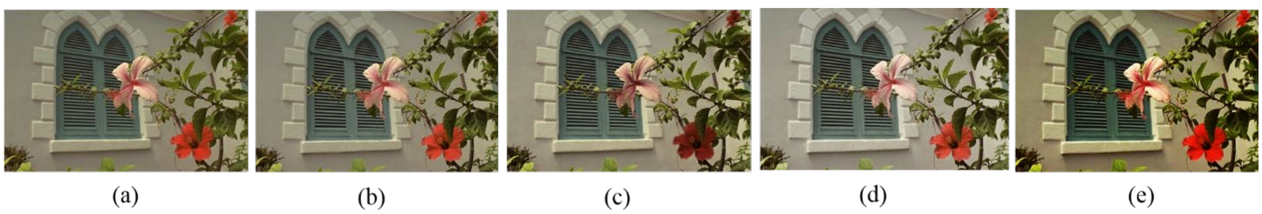

Figure 8 Test image *Window:* (a) Original image, Results obtained for S-type enhancement on grayscale and mapped to color scale by (b) NM, c) CC, d) HPCE, e) NHPCE

Figure 9 Test image from Berkeley dataset: (a) Original image, Results obtained for S-type enhancement on grayscale and mapped to color scale by (b) NM, c) CC, d) HPCE, e) NHPCE

Figure 10 Test image from Berkeley dataset: (a) Original image, Results obtained for S-type enhancement on grayscale and mapped to color scale by (b) NM, c) CC, d) HPCE, e) NHPCE

It can be seen from above images that the proposed HPCE scheme is able to retain the hue content of the modified image to a promising extent while enhancing the original image through S- type enhancement. The numerical values for GID and EBCM indicated convincing performance of

HPCE scheme in transferring modification to the color image which has not been depicted as it seemed redundant.

5.2 Objective evaluation results

The quantitative measures are implemented for comparison between the original and the modified images. Fig. 11 shows the CID [34] difference in hue between the original image in Fig. 2 and the modified images.

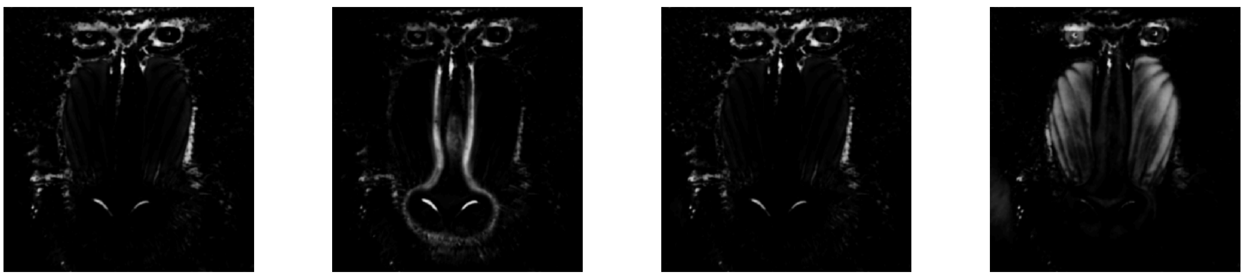

Figure 11 Hue difference calculated using the CID metric between original and NM, CC, HPCE, and NHPCE as 0.03, 0.03, 0.02 and 0.04, respectively.

The number indicates the average hue difference with black indicating no difference and white the largest difference. Further, tests were done on other sets of images and have shown a promising result for the hue-preserving strength of the methodology. Table 1 depicts the quantitative analysis on color images obtained by transferring modifications to color scale images through different techniques. Four different methodologies, i.e., S-type enhancement, WTHE, NMHE and HE has been implemented on the grayscale image of *baboon*, *Cap*, *Birds,* and *Fruits,* respectively. The first two data columns in Table 1 indicate the hue difference metric between original and modified color image, measured by Spatial Hue angle metric (SHAME) [33], Color image difference (CID) [34]. The Gray Image Difference (GID) metric is indicative of the difference in enhanced gray scale image and the image obtained by converting modified color image color to gray scale. A smaller value of this metric indicate better mapping of transformation from grayscale to color image. The last column shows the difference in EBCM value of the enhanced grayscale image and the modified color image converted to grayscale. A low EBCM difference (EBCM-D) indicate that the edges are maximally preserved in newly obtained grayscale images from modified color images.

Table 1 Quantitative measure applied to images obtained by different CIM techniques for Fig. 2, 4-6

Modification	***Baboon***	**SHAME**	**CID**	**GID**	**EBCM-D**

S - type	NM	47.30	0.21	3.71	1.52
	CC	125.01	0.29	20.83	21.36
	HPCE	45.91	0.18	0.29	0
	NHPCE	88.82	0.18	2.46	3.63
	Cap				
WTHE	NM	9.21	0.08	21.69	43.15
	CC	69.52	0.27	12.97	13.44
	HPCE	98.61	0.26	0.29	0.6
	NHPCE	101.74	0.29	1.76	1.45
	Birds				
NMHE	NM	2.40	0.03	6.10	14.39
	CC	128.92	0.17	17.34	21.12
	HPCE	9.09	0.05	0.26	0.49
	NHPCE	20.53	0.07	1.57	4.3
	Fruits				
HE	NM	205.49	0.27	37.95	63.9
	CC	467.40	0.46	23.56	22.04
	HPCE	137.59	0.27	0.33	0
	NHPCE	173.10	0.22	1.75	3.01

One can notice from Table 1 that the performance of HPCE scheme is comparable to NM in hue difference metrics while yielding a remarkable performance in the GID and EBCM difference measure. It indicates that the image obtained through HPCE scheme is able to pass on the transformation to color image reliably and the change in hue is indicative of the modification carried out in the image.

To elucidate the results further, S-Type enhancement, WTHE [39], NMHE [40] and HE has been applied to Berkeley image dataset of 500 images [41]. The resultant modification in grayscale has been then transferred to all three scales via NM, CC, HPCE, and NHPCE. These resultant color scale images are compared via the image difference metrics, that is, SHAME, CID, GID and EBCM difference. A lower value of these metrics indicate better transformation mapping during the process.

Table 2 Showing average of different metrics for Berkeley image dataset for different CIM techniques

Modification type	Gray to color transformation scheme	SHAME	CID	GID	EBCM difference
S_Type	NM	78.71	0.27	3.23	3.76
	CC	85.5	0.28	10.54	11.2
	HPCE	78.48	0.26	0.26	0
	NHPCE	88.82	0.24	0.56	1.67
WTHE	NM	140.23	0.23	23.33	37.27
	CC	72.36	0.23	13.82	17.34
	HPCE	87.99	0.25	0.29	0.33
	NHPCE	169.26	0.26	1.21	1.73
NMHE	NM	41.69	0.09	11.41	20.47
	CC	44.74	0.14	13.77	19.14

	HPCE	47.46	0.13	0.26	0.28
	NHPCE	80.66	0.14	0.92	1.48
HE	NM	306.13	0.41	34.61	47.37
	CC	156.08	0.39	14.93	16.35
	HPCE	202.57	0.45	0.35	0
	NHPCE	407.48	0.46	2.9	3.89

Table 2 analyses the performance of proposed scheme as compared to other gray to color transformation schemes on Berkeley 500 image dataset. The proposed HPCE scheme is comparable to the NM method for hue difference metric SHAME and CID, and occurs due to the modifications occurring in the image. However, the HPCE scheme has least value for GID and EBCM difference metrics, indicating their ability to map the transformation better as compared to the other schemes. This, poses a query as to whether hue preservation is really required during color image modification? The color content of a pixel is directly proportional to the intensity of the different color spectrum falling on its sensor. And thus, if the gray image transformation leads to a change in the luminance scale, the corresponding color image will also have the effect on it hue content proportionally. It is under this proposition that the proposed scheme is found to have a change in hue but without any gamut mapping issue.

In order to provide more clarity, the metric values for the Berkeley dataset are plotted for NM, CC, HPCE, and NHPCE schemes with two different modifications, that is, S-type enhancement and NMHE, in Fig. 12 and Fig. 13, respectively. The values for Fig 12 (a-c) and Fig. 13 (a-c) are sorted in ascending order for clarity.

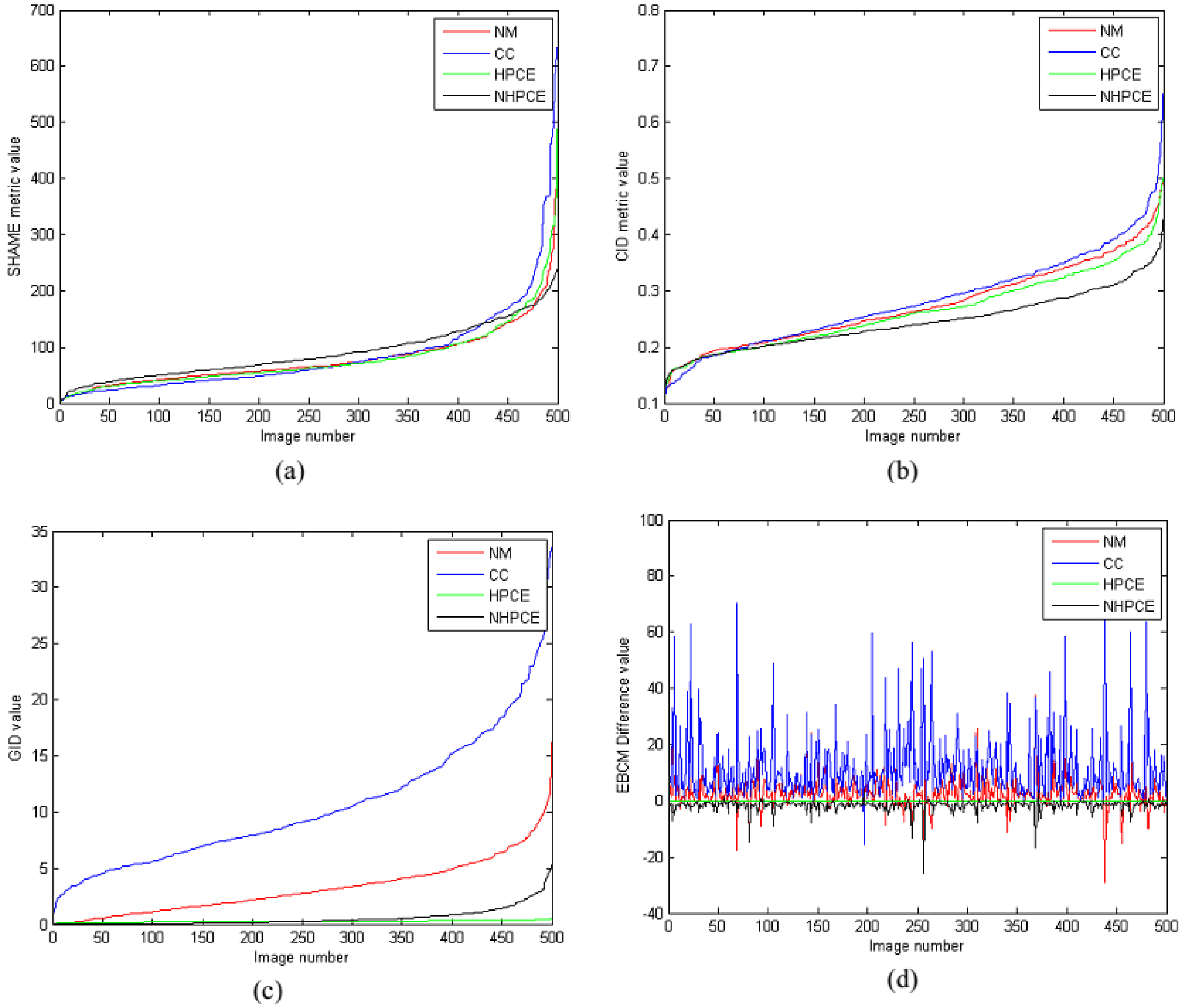

Figure 12 Graphical representation for different metrics with S-type enhancement: a) SHAME b) CID c) GID & d) Difference in EBCM

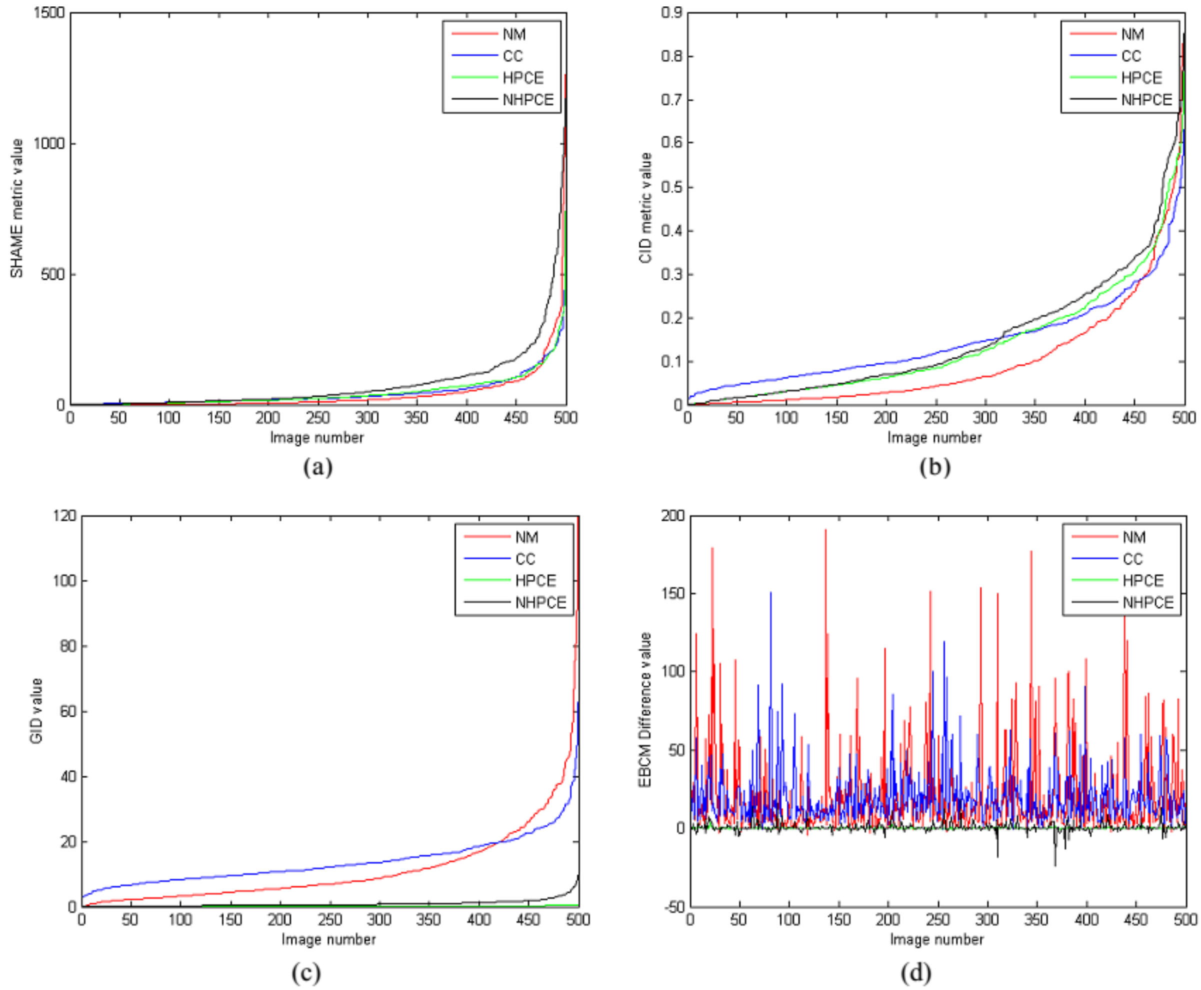

Figure 13 Graphical representation for different metrics with NMHE enhancement a) SHAME b) CID c) GID & d) Difference in EBCM

As seen, the proposed HPCE scheme perform better in terms of GID and EBCM difference metric. The proposed methodology HPCE shown in green color is found to perform well and is able to map the transformation from gray scale to the color image promisingly. The SHAME and CID metrics are only indicators of chromaticity content and is provided here to measure the change in color that occur during transformations. It is although not possible to maintain same chromaticity content while making changes in the gray-scale levels, as it is an abstract representation of color component which should correspond to each other.

6. Conclusion

The paper presents a generic approach for transferring the grayscale modifications to color images without any gamut mapping problem. HPCE being hue preserving in nature can transfer modifications with least change in color while maintaining the exactness of gray scale transformation in color scale. The proposed approach does not require the enhancement function to be represented by a generalized non-linear equation. As a result, any generic modification developed for luminance scale can be directly applied to the color image using the procedure developed here, rendering a true replication on the color scale. In order to prove the efficacy of the proposed technique, qualitative and quantitative analysis have been carried out for the proposed methodology and compared with other gray to color scale transformation schemes. The experimental analysis on Berkeley dataset of 500 images provide convincing performance of the proposed methodology as compared to other techniques for mapping transformation from gray to color scale.

7. References

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