Color Transfer between Images.

What has been done in this research?

This research paper provides a method that includes methods for color correction by providing color characteristics of another image. This is achieved by making use of a simple algorithm where the core focus is to choose a space and apply simple operations there. The authors of our research paper point to Ruderman (source 2) which explains a color space lαβ. This space is not been applied as of yet so our authors apply it.

This research paper talks about multiple things such as: Decorrelated color space, Statistics and Color correction, Gamma correction, Hue correction & Color space.

Decorrelated color space.

In Decorrelated color space research has been done that how to manipulate RGB images by converting them into an XYZ tristimulus values.

The International Telecommunications Union standard matrix is used and multiplied with xyz in column vector form and equated to the (111) ^T. Then we solve the system for XYZ by inverting the matrix and multiplying by 111 columns. The image is converted to LMS space using source 4. These two matrixes are then combined to give a transformation between RGB and LMS cone space. To reduce skews, the log is taken as prescribed by source 2.

In the research on this topic it has been proved that a color space with decorrelated axes is a useful tool for manipulating color images.

Color Correction.

In Color correction research has been done that how to make a synthetic image take on another image's looked and feel images.

For this purpose, we compute the mean and standard deviations along each of the three axes suffice for the source and target images. First, we subtract the mean from the data points as shown in source 10. Then, we scale the data points by factors determined by the respective standard deviations using source 11. Next, we add the averages computed for the photograph. Finally, we convert the result back to RGB via log LMS, LMS, and XYZ color spaces using source 8 and 9.

In the research on this topic it has been proved that imposing mean and standard deviation onto the data points produces believable output images given suitable input images.

Gama correction

Gama correction is an advancement of color correction, as in color correction the mean and standard deviations are manipulated in lαβ space, followed by a transform back to LMS space, we can obtain the same results whether or not the LMS colors are first gamma corrected.

So gamma correction is invariant to shifting and scaling in logarithmic lαβ space. Although gamma correction isn't invariant to a transform from RGB to LMS.

In the research it has been proved that in practice, we can often ignore gamma correction, which is beneficial because source images tend to be of unknown gamma value.

Color Space.

In Color Space research has been done that how to show the significance of choosing the right color space. For this, three different color spaces are compared. The three color spaces are RGB, CIECAM97s and lαβ.

In the research on this topic it has been proved that in lαβ color space, we can also assess the choice of color space on our color correction algorithm.

After understanding this article we can foresee that researchers can successfully use lαβ color space for other tasks such as color quantization and etc.

How this research is important.

Altering an image by removing undesirable and strong colors from the photos has always been an integral part of image processing. This research put forward a method of borrowing another image's color characteristics and helped us apply that color borrowed to another target image. A suitable color space is chosen and different operations are applied on it. This helped produce images that were more visually appealing. This is what companies and brands use today to their advantage to attract customers by producing attracting images that they know will attract the clients and customers. Sometimes, just removing a dominant and undesirable color from the image can be a goal too. The research demonstrated that fairly dramatic transfers are also possible while still producing believable results. This research also proved that creating altered images using a variety of shades of the same color was also possible and did a credible job in producing visually pleasing images. Nudging some of the statistics also produced visually appealing results according to the research paper. The research also shows that using the lαβ color space and gray world assumption, we can apply hue correction on the images to remove color distortion and overall balance the image in a neutral way as it adjusts the color, saturation, and lightness of the entire image. This hue correction can also be performed on a single color grade of an image if the whole image apart from that one color guarantees satisfaction. The research paper also confirms that we can remove gamma correction from an image which will prove beneficial as gamma values are of unknown value in source images. The research paper also reinforces the fact that the proper choice of a color space is crucial according to varying desired images. If proper color space is not chosen, the opposite effect will be achieved.

How the referenced papers are connected with the research.

Source 1:

The research paper had to render water images as well and change their colors. This task was accomplished by making use of the illumination techniques used by the source 1 research paper. The source 1 research paper made use of light illumination of the ocean waves in order to model the wave formation accurately. Source 1 also included external factors such as wind direction and wind speed to make sure that the ocean/water body can be rendered into computer science by using a light transport approach. This will also help in demonstrating models for different water bodies such as Deep Ocean, muddy coastal waters and fresh water bodies. Color transfer research makes use of the technique to first simulate the waves and then render the image by applying colors of another image to finally produce a color processed image.

http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.4.6262&rep=rep1&type=pdf

Source 2:

This research paper explained how the human eye focuses on natural images, and recorded the human cone receptors reaction. (this approach they made use of another research paper of Webster Mollan) with a notable difference of studying the statistical average over images (hence our paper using statistics for color correction). To eliminate the skew, our research paper made use of source 2 method to get rid of it. This was converted into a logarithmic space like source 2 which helped reduce data skew. Also the values of L,M,S principle axis were taken from the research paper with each axis being a logarithmic cone response axis. Then the color correction was performed by our research paper on each channels separately to simplify the process. After this, our research paper subtracted the standard deviation of each channel and then scaled the standard deviations to produce resulting standard deviations that allows the color corrected image to conform to the picture that we took the colors from.

Statistics and color correction

The goal of our work is to make a synthetic image take on another image's look and feel. More formally this means that we would like some aspects of the distribution of data points in $l\alpha\beta$ space to transfer between images. For our purposes, the mean and standard deviations along each of the three axes suffice. Thus, we compute these measures for both the source and target images. Note that we compute the means and standard deviations for each axis separately in $l\alpha\beta$ space.

First, we subtract the mean from the data points:

$$\begin{aligned} l^{*} &= l - \langle l \rangle \\ \alpha^{*} &= \alpha - \langle \alpha \rangle \\ \beta^{*} &= \beta - \langle \beta \rangle \end{aligned} \tag{10}$$

$$\begin{bmatrix} l \\ \alpha \\ \beta \end{bmatrix} = \begin{bmatrix} \frac{1}{\sqrt{3}} & 0 & 0 \\ 0 & \frac{1}{\sqrt{6}} & 0 \\ 0 & 0 & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & -2 \\ 1 & -1 & 0 \end{bmatrix} \begin{bmatrix} \mathbf{L} \\ \mathbf{M} \\ \mathbf{S} \end{bmatrix}$$

Weber–Fechner law states that uniform logarithmic changes in stimulus intensity tend to be equally detectable (see, for example, Ref. 20). Thus in a logarithmic space the perceptual noise level is uniform throughout. This law, however, does not hold universally (especially for small stimuli), so its role as a motivating factor for a logarithmic transformation is somewhat less than that of simply improving the data's symmetry.

The coordinate transformation is as follows. Each of the three quantal catches of a given image is converted to a logarithmic signal (base 10), whose mean is subtracted away:

$$\mathcal{L} = \log L - \langle \log L \rangle,$$
$$\mathcal{M} = \log M - \langle \log M \rangle,$$
$$\mathcal{S} = \log S - \langle \log S \rangle. \tag{1}$$

Here $\mathcal{L}$ is the new logarithmic signal for L, and $\langle \log L \rangle$ is the mean of $\log L$ over the image. By subtracting the mean, we are able to assess the responses without regard to an overall illumination level. This is analogous to a von Kries adaptation procedure, where each cone's set of responses is normalized independently.[19] Statistics of log-transformed natural images have been previously analyzed,[9,10] and are known to have second-order statistics similar to those of linear images.[21]

A. Choosing a Coordinate System

Before proceeding with the analysis, we considered two compelling reasons for expressing our data in an im-

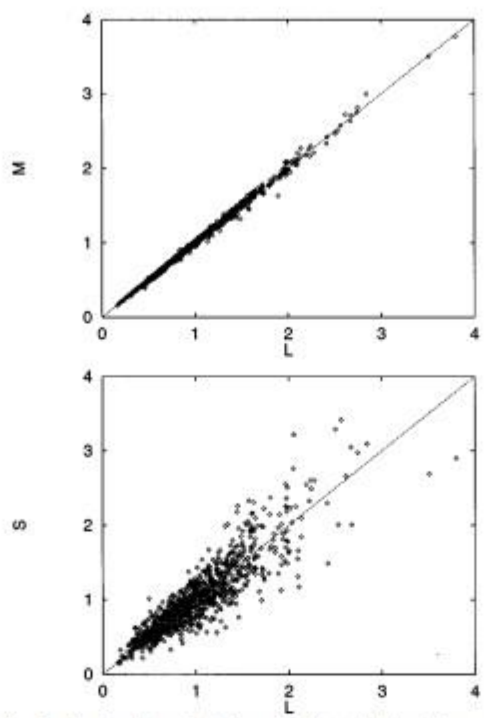


Fig. 1. Scatterplots of (top) L-versus-M and (bottom) L-versus-S data from 1000 pixels chosen at random from the image data set. The distributions show a high degree of correlation and asymmetry. Values are scaled so that the mean along each axis is 1.

of the space. The columns of the A matrix then have meaning as the basic directions of fluctuation within the data. If the data instead occupy the space sparsely, then higher-order correlations are implied between the x's, making the intuition less complete. Our data are of the former character, as we show in Subsection 3.C.

The analysis is straightforward and gives approximately the following three orthonormal principal axes:

$$\hat{l} = \frac{1}{\sqrt{3}}(\hat{\mathcal{L}} + \hat{\mathcal{M}} + \hat{\mathcal{S}}),$$
$$\hat{\alpha} = \frac{1}{\sqrt{6}}(\hat{\mathcal{L}} + \hat{\mathcal{M}} - 2\hat{\mathcal{S}}),$$
$$\hat{\beta} = \frac{1}{\sqrt{2}}(\hat{\mathcal{L}} - \hat{\mathcal{M}}), \tag{4}$$

where $\hat{\mathcal{L}}$, $\hat{\mathcal{M}}$, and $\hat{\mathcal{S}}$ are the unit direction vectors in the logarithmic cone response space. The actual coefficient values correspond very closely to these integer values and are shown in Table 1. Note that these axes are precisely those suggested as a convenient set by Flanagan *et al.*[23] (in an appendix). The standard deviations of the data along each of the three axes are $\sigma_l = 0.353$, $\sigma_\alpha = 0.0732$, and $\sigma_\beta = 0.00745$, a ratio of 47:9.8:1. These

Source 3:

https://books.google.com.pk/books?hl=en&lr=&id=ccIZ2vi5W2wC&oi=fnd&pg=PR11&dq=D.R.+Laming,+Sensory+Analysis,+Academic+Press,+free&ots=LKL5h1yAp&sig=4hgDmzpdrEtg04AkWViPdanWr2I#v=onepage&q&f=false

To make sure that the changes in our image are easily detectable without any illusions, the sensory analysis was used to make sure the changes in intensity may be equally detectable unlike in the Craik-Cornsweet illusion. Our research paper made use of source 3 analysis. There is a less relation in our l and β axis, so to make sure that when we apply operations on these unrelated axis, the final result is more believable. Helps in the achromatic channel.

Source 4:

The matrix and algorithm used by our research paper for converting an image into the LMS space was achieved by using the matrix presented in this book. The matrix was multiplied with the device dependent xyz spaces.

stitutes a small adjustment to the matrix's values.

Once in device-independent XYZ space, we can convert the image to LMS space using the following conversion:[4]

$$\begin{bmatrix} L \\ M \\ S \end{bmatrix} = \begin{bmatrix} 0.3897 & 0.6890 & -0.0787 \\ -0.2298 & 1.1834 & 0.0464 \\ 0.0000 & 0.0000 & 1.0000 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \qquad (3)$$

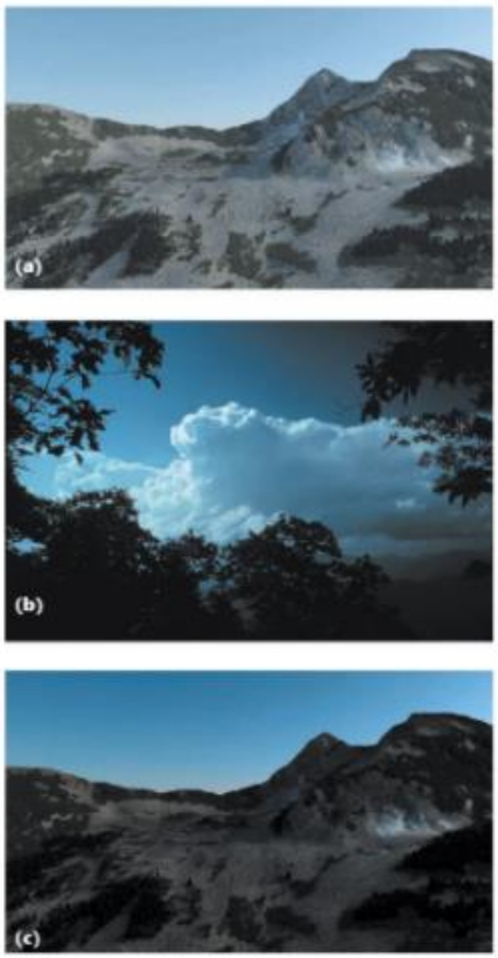
Source 5:

This paper produced a finding. The finding was that the color space used for LMS color space was only possible to be mapped as the achromatic axis orthogonal to the yellow-blue and red-green space. This property is also shared by our research paper where the first axis and the rest two are orthogonal. This property let our lαβ color space could treat the channels separately as well which makes the method simple. This property allows the color processing from the lαβ color space to the LMS color space of the paper.

Source 6:

There is a problem in color corrections. If our original image is extremely different from the image we extract colors from, the results may not be very appealing. To fix this problem, the research paper has presented somewhat of a solution. Fairly dramatic differences of pictures were still mapped on color corrected images to produce believable results. The mountain picture was used of this paper and then mapped with colors of a skyline shot. This is done thanks to their statistics and color correction. Shading and shadow effects can be removed and customized additions of 3D instances such as trees etc can also be added.

https://www.cs.utah.edu/~thompson/publications/Premoze:1999:GRA.pdf



3 Different times of day. (a) Rendered image[6] (image courtesy of Simon Premoze), (b) photograph (courtesy of the NOAA Photo Library), and (c) corrected rendering.

Source 7:

Pattanik's chromatic adaption algorithm is used to provide hue correction. This algorithm also made use in the NPR shading of David. The effect of the light source on an image is completely removed by hue correction to produce an image that is completely independent of a light source by using the gray world assumption. The picture of apple one was used for the color illumination. https://www.graphicon.ru/oldgr/library/siggraph/98/papers/pattanai/pattanai.pdf tion 1.

$$\begin{vmatrix} L \\ M \\ S \end{vmatrix} = \begin{vmatrix} 0.3897 & 0.6890 & -0.0787 \\ -0.2298 & 1.1834 & 0.0464 \\ 0 & 0 & 1 \end{vmatrix} \begin{vmatrix} X \\ Y \\ Z \end{vmatrix} \quad (1)$$

However, it is impossible to obtain the proper rod signals. We derived a linear transform of XYZ tristimulus values as a rough approximation to the rod signal via linear regression of the color matching functions and the $V'(\lambda)$ curve. The resulting transform is given in Equation 2 where R represents the rod response for a pixel.

$$R = -0.702X + 1.039Y + 0.433Z \quad (2)$$

Since it is possible to obtain negative values of R when Equation 2 is applied to some saturated colors, it must be clipped to zero. We chose a simple linear transformation for this approximation since it scales over any range of luminance levels.

Finally the input signals must be calibrated prior to input to the visual transforms. We chose to calibrate the model such that the LMS cone signals and the rod signal are all equal to unity for an equal-radiance spectrum at a luminance of 1.0 cd/m^2.

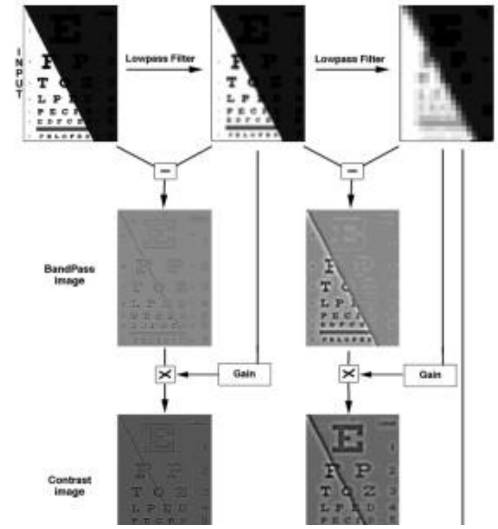


Figure 10: Illustration of chromatic adaptation.

Malik [1997]. To provide the higher degree of compression necessary for high-dynamic-range mapping, the low pass image was adapted to itself. The reproduced images were reconstructed for display at a mean luminance of 50 cd/m^2.

The images on the top row of Figure 11 are linear mappings of the original high-dynamic range images into the limited dynamic range of the output device. The original images had luminance ranges of approximately 10,000:1. The images on the bottom row represent the mapping obtained by application of the visual model. In Figure 11 it is clear that far more detail can be observed in both

portant. Potential application areas include: image quality metrics; image coding and compression methods; perceptually-based image synthesis algorithms; image-based rendering; and advanced display system design.

There is still much work to be done in this area. First, this is a static model of vision. Future models should incorporate knowledge about the temporal aspects of visual processing in order to allow both dynamic scenes, and scenes where the level of illumination is dynamically changing to be properly displayed. Second, we hope to integrate our visual model with ongoing work in the

For the automatic npr of michaelangelo the same algorithm is also used.

NPR References.

Now sources of the Michael angelo:

Source 1:

Figure 2: *How the tone is created for a pure red object by summing a blue-to-yellow and a dark-red-to-red tone.*

created by adding grey to a certain color they are called *tones* [2]. Such tones vary in hue but do not typically vary much in luminance. When the complement of a color is used to create a color scale, they are also called tones. Tones are considered a crucial concept to illustrators, and are especially useful when the illustrator is restricted to a small luminance range [12]. Another quality of color used by artists is the *temperature* of the color. The temperature of a color is defined as being warm (red, orange, and yellow), cool (blue, violet, and green), or temperate (red-violets and yellow-greens). The depth cue comes from the perception that cool colors recede while warm colors advance. In addition, object colors change temperature in sunlit scenes because cool skylight and warm sunlight vary in relative contribution across the surface, so there may be ecological reasons to expect humans to be sensitive to color temperature variation. Not only is the temperature of a hue dependent upon the hue itself, but this advancing and receding relationship is effected by proximity [4]. We will use these techniques and their psychophysical relationship as the basis for our model.

We can generalize the classic computer graphics shading model to experiment with tones by using the cosine term ($\hat{\mathbf{l}} \cdot \hat{\mathbf{n}}$) of Equation 1 to blend between two RGB colors, k_{cool} and k_{warm}:

$$I = \left(\frac{1 + \hat{\mathbf{l}} \cdot \hat{\mathbf{n}}}{2}\right) k_{cool} + \left(1 - \frac{1 + \hat{\mathbf{l}} \cdot \hat{\mathbf{n}}}{2}\right) k_{warm} \qquad (2)$$

Note that the quantity $\hat{\mathbf{l}} \cdot \hat{\mathbf{n}}$ varies over the interval $[-1, 1]$. To ensure the image shows this full variation, the light vector $\hat{\mathbf{l}}$ should be perpendicular to the gaze direction. Because the human vision system assumes illumination comes from above [9], we chose to position the light up and to the right and to keep this position constant.

An image that uses a color scale with little luminance variation is shown in Figure 6. This image shows that a sense of depth can be communicated at least partially by a hue shift. However, the lack of a strong cool to warm hue shift and the lack of a luminance shift makes the shape information subtle. We speculate that the unnatural colors are also problematic.

In order to automate this hue shift technique and to add some luminance variation to our use of tones, we can examine two extreme possibilities for color scale generation: blue to yellow tones and

Plugging these values into Equation 2 leaves us with four free parameters: b, y, α, and β. The values for b and y will determine the strength of the overall temperature shift, and the values of α and β will determine the prominence of the object color and the strength of the luminance shift. Because we want to stay away from shading which will visually interfere with black and white, we should supply intermediate values for these constants. An example of a resulting tone for a pure red object is shown in Figure 2.

Substituting the values for k_{cool} and k_{warm} from Equation 3 into the tone Equation 2 results in shading with values within the middle luminance range as desired. Figure 7 is shown with $b = 0.4$, $y = 0.4$, $\alpha = 0.2$, and $\beta = 0.6$. To show that the exact values are not crucial to appropriate appearance, the same model is shown in Figure 8 with $b = 0.55$, $y = 0.3$, $\alpha = 0.25$, and $\beta = 0.5$. Unlike Figure 5, subtleties of shape in the claws are visible in Figures 7 and 8.

The model is appropriate for a range of object colors. Both traditional shading and the new tone-based shading are applied to a set of spheres in Figure 9. Note that with the new shading method objects retain their "color name" so colors can still be used to differentiate objects like countries on a political map, but the intensities used do not interfere with the clear perception of black edge lines and white highlights.

4.3 Shading of Metal Objects

Illustrators use a different technique to communicate whether or not an object is made of metal. In practice illustrators represent a metallic surface by alternating dark and light bands. This technique is the artistic representation of real effects that can be seen on milled metal parts, such as those found on cars or appliances. Milling creates what is known as "anisotropic reflection." Lines are streaked in the direction of the axis of minimum curvature, parallel to the milling axis. Interestingly, this visual convention is used even for smooth metal objects [15, 18]. This convention emphasizes that realism is not the primary goal of technical illustration.

To simulate a milled object, we map a set of twenty stripes of varying intensity along the parametric axis of maximum curvature. The stripes are random intensities between 0.0 and 0.5 with the stripe closest to the light source direction overwritten with white. Between the stripe centers the colors are linearly interpolated. An object is shown Phong-shaded, metal-shaded (with and without

http://artis.imag.fr/~Cyril.Soler/DEA/NonPhotoRealisticRendering/Papers/p447-gooch.pdf

The concept of warm and cold areas was used by our paper by using the research of source 1. The idea of shading different instances was also introduced in this research paper. By setting different control points different base colors can be set. However, a drawback is that it may produce poor results due to the non-uniformity of colors. The concept was not directly used but rather built upon off by source 2. For example at the underarm of david, there is a dark shade, it was darkened with respect to a shadow showing coldness.

Source 2:

The method of research paper 1 was built upon by introducing shading different regions for objects by making use of different data sets for different objects like cold and warm places. This helps to produce even more pleasing results but with added user interaction as there are more color sets to choose from. A color base object is selected and then mapped on to the original picture with shades. Our paper builds on this concept by recording the colors of an external image (source 3) image and then applying their color statistics method. Now instead of using base colors yourself (it was time consuming) we can directly add a base color.
https://www.cs.princeton.edu/courses/archive/fall00/cs597b/papers/rademacher99.pdf

Source 3:

The color of the models back was used as a base to map onto Michelangelo's sculpture. This image of the model became the backbone for conventional JPEG. It was because of its high resolution for study of color image processing. The original researchers in University of South California used this image up to the shoulder for glossy colors. This color tone of the models back was used by our paper as base color and mapped onto David. David is originally grey, but as we made use of base color and color correction, we applied them on our NPR model to produce a new result. User intervention is now limited and the problem of source 2 is now solved by using a swatch to shade the model correctly.

What can be future directions of the research?

The goal of this research is to applying the colors of one image to another by using simple algorithms and suitable color space.

Following are the future directions of provided research paper:

1. Color Quantization:

In computer graphics, color quantization or color image quantization is quantization applied to color spaces; it is a process that reduces the number of distinct colors used in an image, usually with the intention that the new image should be as visually similar as possible to the original image. Computer algorithms to perform color quantization on bitmaps have been studied since the 1970s. Color quantization is critical for displaying images with many colors on devices that can only display a limited number of colors, usually due to memory limitations, and enables efficient compression of certain types of images.

The name "color quantization" is primarily used in computer graphics research literature; in applications, terms such as optimized palette generation, optimal palette generation, or decreasing color depth are used.

2. We can use the range of colors measured in photographs to restrict the color selection to ones that are likely to occur in nature.

3. Subtle post processing on images to improve their appearance to more dramatic alterations, such as converting a daylight image into a night scene.
4. The synthetic image and the pho-to graph have similar compositions, so we can transfer the photograph’s appearance to the synthetic image.
5. User intervention is now limited to choosing inappropriate swatch, creating proper NPR shading models is now straightforward and produces credible results.
6. Image processing:

This research will also help in image processing.

- Gamma correction:

  It can have impacts on gameplay (for example, if you look down a dark hallway, players using correct settings may just see red eyes, while someone at full brightness may see the shape of the object with the eyes), but in general these shouldn't be major.

7. Plug-ins for various commercial graphics packages.

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