Colour correction for panoramic imaging

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Abstract: This paper reports the problem of colour distortion in panoramic imaging. Particularly when image mosaic is used for panoramic imaging, the images are captured under different lighting conditions and viewpoints. The paper analyses several linear approaches for their colour transform and mapping. A new approach of colour histogram based colour correction is provided, which is robust to image capturing conditions such as viewpoints and scaling. The procedure for the colour correction is introduced and implemented. The conclusions are derived after experimental tests.

1. Introduction

Panoramic images are used as a computerised "virtual view" visualisation of the real world. A panorama can show a user the 3D environment of a different location. For example if a person goes on holiday, they might capture a panorama of their holiday location and then show that to people back home whom could then visualise the holiday as though they themselves had been there. Some other uses for panoramas involve virtual environment visualisation, real estate, tourism, sporting and news events.

Panoramas are usually built from multiple images captured at a single location. Examples of captured images might be 15 images captured in a cylindrical format using a standard 35mm camera rotated about the optical centre of the camera, or 2 hemispherical images captured using a 180° field of view fisheye lens, one in each direction. The images that are captured have to be "stitched" together to form the final panoramic image. Unfortunately when capturing the images, the automatic exposure control in cameras can and does change the exposure between captures. This translates into a possible underexposed dark image and the next in the sequence being an overexposed bright image. Examples of differently exposed images are shown in Fig. 1. Particularly, some automatic embedded compensation algorithms in modern cameras don't work well.

Fig.1 Two Panoramic source images with different exposures by the same camera

Image stitching for panoramas will apply the individual images with overlap [1-2] or without overlap from video sequences to integrate together [3]. In reality, the source images may be from different cameras, which are normally not calibrated or difficult to calibrate [4]. To be stitched properly, linear transforms have been used for geometric mapping and colour mapping [1-2]. There are many papers that discuss correspondence point based homography for geometric transform and correction [5-9]. But the reports on colour transform and correction, which is important to human perception, are ignored in panoramic imaging. In this paper, we will investigate the colour transformation and colour correction among panoramic images. The rest of the paper is organised as: Section 2 discusses the colour transform among two images and their colour correction; Section 3 provides a new approach of histogram based colour correction for image stitching for panoramas; Section 4 introduces experimental results using different line transform for colour correction and their results on panoramas; Finally, some conclusions will be derived from the discussion.

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2. Colour correction and colour constancy

The digital camera records large shifts in image colours under different illuminations. However, a human observer viewing each scene will be able to discount the colour of the illumination and perceive the colours in each scene as the same. This property of compensating for illumination is called colour constancy [10]. Colour constancy is a subconscious colour correction that all humans have. In the study, we try to overcome the problem of colour distortion by capturing images under different lighting or different camera properties by linear colour correction. To do this, we need to understand the principle of colour variation between the two images.

The machine colour constancy problem can be defined as follows. First, chose some illumination as the standard, or canonical, illumination. The choice of canonical illumination matters little so long as it is not unusual. Then consider the 3 band RGB image obtained by any standard colour camera of a scene under some other, unknown illumination. The machine colour constancy problem requires converting the RGB at every pixel to be what it would have been had the same scene been illuminated by the canonical illumination. In this way, all the RGB values in the image of the scene measured under the unknown illumination are converted to standardized RGB descriptors relative to the canonical illuminant. Once these standardized descriptors have been obtained, they can be used for object recognition or for creating an image of the scene as it would appear under some other illuminant. The key to solving this problem is discovering the colour of the unknown illumination.

Two well-known colour constancy methods, which work under limited circumstances, are the grey world algorithm and the white patch algorithm. The grey world algorithm assumes that the average of all colours in an image is grey, i.e. the red, green and blue components of the average colour are equal. The amount the image average differs from grey determines the illuminant RGB. The white patch algorithm, which is at the heart of many of the various retinex [11] algorithms, presumes that in every image there will be some surface or surfaces such that there will be a point or points of maximal reflectance for each of the R, G, and B bands.

For example left image in Fig.1 might want to have the same lighting as the right image, which is what human vision systems do. A common approach to colour constancy is the use of the estimation illumination to correct the images to a canonical light. Finlayson et al [12] suggested that if a transform is linear, a diagonal model might be sufficient to model the colour transform. Generally colour cameras are tri-chromatic, which means in a colour image, each pixel is a 3 vector, one component per sensor channel and works independently. However, with the increasing colour fidelity, more accurate transform will be required [13]. Different linear colour transforms, where the colour variation may be caused by lighting, viewpoints or capturing devices, are discussed as follows. The transform Matrix M cross images I_1 and I_2 can be represented as

$$I_1 * M = I_2 \tag{1}$$

1) Diagonal model

$$M = \begin{bmatrix} \alpha & & \\ & \beta & \\ & & \gamma \end{bmatrix} \tag{2}$$

$\alpha = \frac{mean(R_2)}{mean(R_1)}$, where R is the red channel image intensity values in the two images. β and γ are similar for green and blue channels.

General features:

- Simple, not accurate enough
- Based on greyworld principle and does not need same pixels in the 2 images

2) Diagonal model plus affine transform

$$M = \begin{bmatrix} \alpha & & & \alpha_1 \\ & \beta & & \beta_1 \\ & & \gamma & \gamma_1 \end{bmatrix} \tag{3}$$

α, β, γ and offset $\alpha_1, \beta_1, \gamma_1$ can be obtained from polyfit in the individual channels.

General features:

- More accurate than diagonal model
- Two images have the same corresponding pixels

3) Linear model

$$M = \begin{bmatrix} a & b & c \\ d & e & f \\ g & h & i \end{bmatrix} \qquad (4)$$

Where can be computed by

$$M = \left[I_1^T I_1 \right]^{-1} I_1^T I_2 \qquad (5)$$

Where I_1, I_2 is [n, 3] matrix and n is the number of pixels in the images.

General features:

- Good accuracy
- Need the same corresponding pixels in both images
- Computationally expensive

4) Linear model with affine:

$$M = \begin{bmatrix} a & b & c & a_1 \\ d & e & f & e_1 \\ g & h & i & i_1 \end{bmatrix} \qquad (6)$$

In addition to equation (5), the offset can be obtained by

$$\begin{bmatrix} a_1 \\ e_1 \\ i_i \end{bmatrix} = \begin{bmatrix} mean(R_2) \\ mean(G_2) \\ mean(B_2) \end{bmatrix} - \begin{bmatrix} a & b & c \\ d & e & f \\ g & h & i \end{bmatrix} \times \begin{bmatrix} mean(R_1) \\ mean(G_1) \\ mean(B_1) \end{bmatrix} \qquad (7)$$

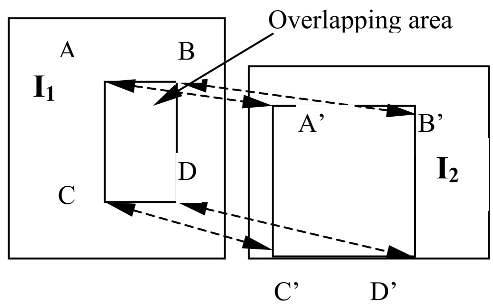
The general features are the same as the linear model in 3).

As described above, to obtain better colour correction, more parameters in linear transforms will be used. We will use and compare diagonal model plus affine transform, linear model and linear model plus affine for colour correction in image correction for the panorama.

3. Histogram map based colour correction

Colour and brightness variations often make it difficult to combine photographs into panoramic images [14]. The individual source images remain distinguishable. This effect counteracts any effort to improve panorama resolution by using many photographs as sources. There are several origins for these variations even if the photographer takes care to keep constant exposure for each image: 1) Change of lighting conditions during the photo session; 2) Shutter speed variations; 3) Many more random and non reproducible parameters affecting image development and subsequent scanning. Even worse, many exposure related factors are outside the control of the photographer like automatic exposure settings in some cameras and scanners, or scanning services To balance two stitching images, some colour correction is required. The normal approach applies the overlapping region of an image for estimating a colour transform matrix [15]. Due to the variation of capturing conditions such as camera resolution, noise and viewpoints, the pixels in the overlapping area are difficult to correspond to each other. In other words, the overlapping areas in two images may have different pixels due to variations of viewpoints and scaling. The difference of colour values at identical locations is not a very suitable optimization criterion. Real world images never fit together perfectly, and unavoidable spatial errors of one pixel or more between image 1 and image 2 may completely screw the optimization.

To be independent of the spatial alignment of the images and apply general linear models (over 3 parameters in the transform matrix), we use the matching of histograms of colours in the overlapping region of images 1 and 2. Fig 2 illustrates the step 1 process of our approach. A, B, C, D and A', B', C', D' are corresponding points in the two images I_1 and I_2, in which the maximising overlapping area is covered.



Step1 Find maximising overlapping area in the two stitching images

Fig 2 Step 1 of the new approch of color correction

As illustrated in Fig 3, the overlapped areas may have different histograms. We can map the histogram, where A1B1C1D1 area has the same 'geometrical content' as ABCD in image I_1 but has the same histogram as A'B'C'D' in image I_2. Then, in Step 3, we can apply the histogram mapped image for estimating colour transform matrix M, where A1B1C1D1 and ABCD areas have same image pixels with good correspondence. The transform matrix can be calculated by any linear transform as described in section 2. Finally, we can apply the transform matrix for the entire image I_1 or I_2 colour calibration, as shown in Fig 4.

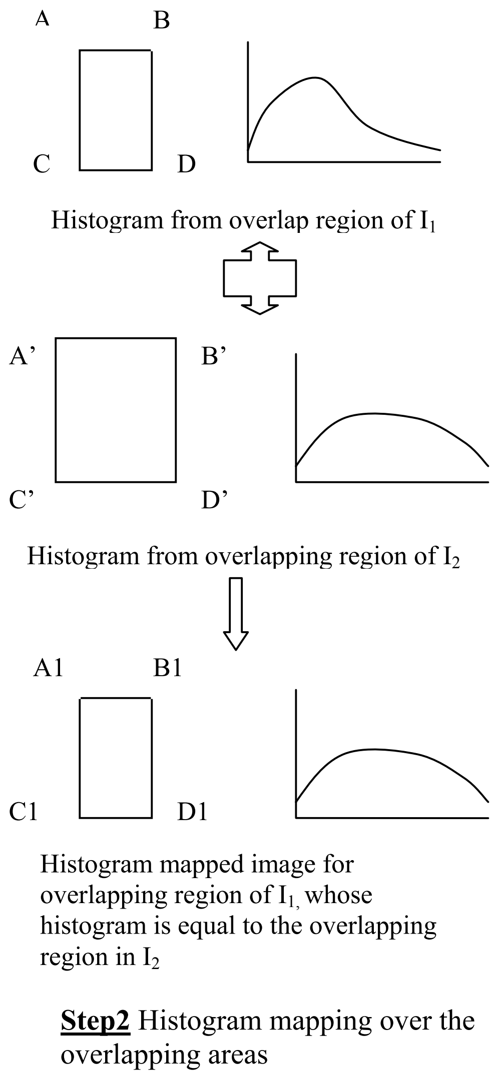


Fig 3 Step 2 of new approch of color correction

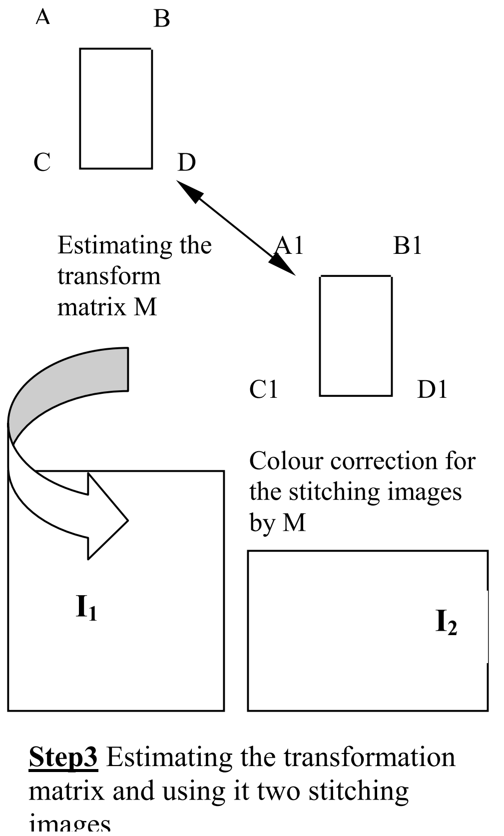


Fig 4 Linear transform matrix estimation and colour correction before image stitching and panorama

4. Colour correction for panoramic imaging

Based on the above-proposed approach, we have applied it for panoramic source image colour corrections. Fig. 5a illustrates the overlapping area from two stitching images in Fig 1. A histogram map will be applied to the two overlapped images. Then, following the steps described in sections 2 and 3, transform matrixes can be estimated by different linear models. Finally, apply the transform matrix for colour correction and image stitching. Fig 5b shows the colour corrected images to image 1 or image 2 capturing conditions.

At the end of the paper, Fig 6 illustrates four panoramic images with the proposed colour correction approach. Linear transformation which considers the correlation of RGB channels can provide slight better results. However, the diagonal model plus affine transform can provide near perfect results.

a) Overlapping area of the stitching images in Fig 1

b) Colour correction based on M or M^{-1}

Fig 5 Histogram based colour correction for image stitching pre-process

5. Conclusions

Colour correction for image mosaic based panoramic imaging is important. Several colour linear transformations have been discussed. The performance of linear models for colour correction is better than the diagonal model. A histogram map based colour correction has been proposed and tested. The major advantages of the histogram mapping approach for colour correction are robust to capturing devices, viewpoints and scales. In other words, the new approach has overcome the problems for stitching images variation including not only colour, but also resolution, view geometry and noise. Different colour correction based different linear transformations can be used in the proposed approach. The choice of linear transformation matrix for colour correction can be affected by the accuracy and computing time. The diagonal model plus affine can provide near perfect results as general linear models. In the future, more panoramic imaging will be tested and evaluated.

6. Acknowledgement

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a) Mini panorama without colour correction processing

b) Minipanorama using dialoganl model plus affine colour correction

d) Mini panorama with linear correction pre-processing

e) Mini panorama with linear plus affine correction pre-processing

Fig 6 Different colour correction for panoramic imaging