EEL5820 – Programming Assignment 1

OBJECTIVE

In this assignment an implementation of the Color Transfer method detailed in a publication "Color Transfer in Correlated Color Space" by Xiao et al. The paper presents a color transfer process which copies the color characteristics of one image onto another. The implementation of the technique has been completed in Matlab, the code of which shall be included with this report.

PROCEDURE

We will consider the pixels in an image as a three dimensioned set of intensity values. These values tell us the intensity of the colors Red, Green, and Blue in an image. The correlation between these values can be measured by way of covariance. To produce an image which captures the sources images color characteristics this method moves data points or attributes of the source image by scaling, rotation and translating to fit the points of the target images in RGB color space.

The mean of the pixel data in each dimension along with the covariance matrix between the three components in color space, for both source and target images, are used to create the scaling, rotation and translating transformation. The mean is obtained by separating the RGB components of the images and finding the separate means of each component. The mean, denoted as $(\overline{R}, \overline{G}, \overline{B})$, shall be used to compose a translation matrix for both the source and target images. The definition of the matrix is shown below.

$$T_{src} = \begin{pmatrix} 1 & 0 & 0 & t_{src}^r \\ 0 & 1 & 0 & t_{src}^g \\ 0 & 0 & 1 & t_{src}^b \\ 0 & 0 & 0 & 1 \end{pmatrix}, T_{tgt} = \begin{pmatrix} 1 & 0 & 0 & t_{tgt}^r \\ 0 & 1 & 0 & t_{tgt}^g \\ 0 & 0 & 1 & t_{tgt}^b \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

To produce the scaling and rotation matrices the singular value decomposition of the source and target image covariance matrices is required.

$$Cov = U \cdot \Lambda \cdot V^T$$

Where U and V are orthogonal matrices composed of the eigenvectors and the covariance matrix and Λ is a diagonal matrix composed of the eigenvalues of the covariance matrix. The rotation and scaling vectors are shown below.

$$R_{src} = U_{src}, R_{tgt} = U_{tgt}^{-1}$$

$$S_{src} = \begin{pmatrix} s_{src}^{r} & 0 & 0 & 0 \\ 0 & s_{src}^{g} & 0 & 0 \\ 0 & 0 & s_{src}^{b} & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}, S_{tgt} = \begin{pmatrix} s_{tgt}^{r} & 0 & 0 & 0 \\ 0 & s_{tgt}^{g} & 0 & 0 \\ 0 & 0 & s_{tgt}^{b} & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Where: $t_{src}^{r} = \overline{R}, t_{src}^{g} = \overline{G}, t_{src}^{b} = \overline{B}$

$$t_{tgt}^{r} = -\overline{R}, t_{tgt}^{g} = -\overline{G}, t_{tgt}^{b} = -\overline{B}$$

$$s_{src}^{r} = \sqrt{\lambda_{srs}^{R}}, s_{src}^{g} = \sqrt{\lambda_{srs}^{G}}, s_{src}^{b} = \sqrt{\lambda_{srs}^{B}}$$

$$s_{tgt}^{r} = 1\Big/\sqrt{\lambda_{tgt}^{R}}, s_{tgt}^{g} = 1\Big/\sqrt{\lambda_{tgt}^{G}}, s_{tgt}^{b} = 1\Big/\sqrt{\lambda_{tgt}^{B}}$$

From here the transformation can be applied as follows:

$$I = T_{src} \cdot R_{src} \cdot S_{src} \cdot S_{tgt} \cdot R_{tgt} \cdot T_{tgt} \cdot I_{tgt}$$

Where I_{tgt} denotes the transpose of the RGB values of the image padded with an 4th dimension of ones, this allow for the matrix product to be taken with the transforms shown above. I contains the transpose of the (R,G,B,1) matrix of color transfer result image values. Removing the 4th dimension of the result matrix and displaying the image without scaling the values results in the image below.

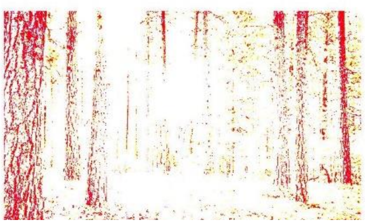

Figure 1

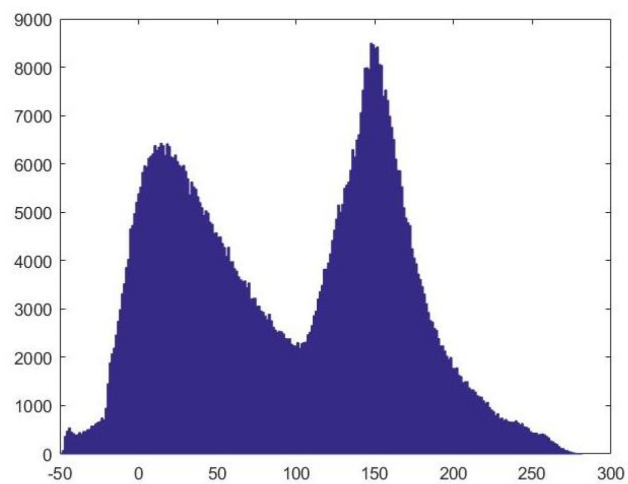

Figure 2 Histogram of Figure 1 Pixel Intensity Values

Figure 1 shows a result of the above transform. No scaling the pixel values of the new image results in a version of the target image that is oversaturated with the color characteristics of the source image. All images used during this trial featured 8-bit color depth, meaning the range of possible values for a single color channel is 0 – 255. As can be seen in figure 2, some intensity values in the resulting image are below the minimum value of 0 and above the maximum of 255. We can scale the values of the image by applying the following scaling function to each pixel $(2^{bit\ depth}-1)(\frac{pixel\ value-Max}{Max-Min})$. The affects of scaling on Figure 2.

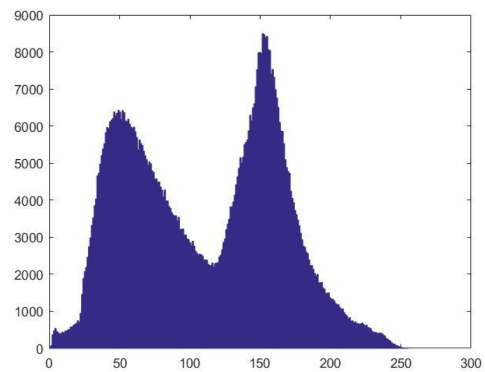

Figure 3 Histogram of Figure 1 Pixel Intensity Values After Scaling

RESULTS

Figure 4 Source and target images with warm and cool color temperatures

Figure 5 Source: Transfer Failure

Figure 6 Effects of cool color temperature on warm image

Figure 7 Effects of cool color temperature on warm image, with subjects

CONCLUSION

The statistics-based method for color transfer implemented for this assignment was effective in transferring muted color temperatures to images. As can be seen in Figure 5, certain color swatches within the source image can cause unpleasant effects on less vibrant images. It was also observed that the best transformation occurred on images were similar in composition and when images contained an even and consistent color temperature. It is for this reason that the authors of the paper reference in this implementation suggest a Swatch-based Transfer method that allows for some user defined control over where swatches or portions of an image will be transferred onto the target.

REFERENCES

Xiao, Xuezhong & Ma, Lizhuang. (2006). Color transfer in correlated color space. Proceedings - VRCIA 2006: ACM International Conference on Virtual Reality Continuum and its Applications. 305-309. 10.1145/1128923.1128974.