Image Processing I

EECE 4353/5353 Fall 2018

Laboratory 3: Color Processing of Images

Due Tuesday 3 October 2018

The goals of this lab are to learn how to (1) apply point operations to the R, G, and B bands of color images to alter their colors, (2) convert images to HSV space, perform operations on those bands, and convert the results back to RGB, and (3) generate a linear color correction matrix from corresponding pixels in two images.

In this lab assignment (and all the others) you will be writing your own image processing functions. You may not use the functions from the MATLAB image processing toolkit by themselves or within your functions to solve the problems in the labs. You may compare the results of your own functions against those of the IP toolkit for your own information but those results may not be used in your lab reports.

Help can be gotten on any MATLAB command (or function) by typing `help command_name`, *e.g.* to get help on `imwrite()`, type `help imwrite` at the command prompt. Another way is to press the <F1> key, select the **index** tab in the window, and type the command name into the search box.

In completing this assignment (and the others) if specific images are not supplied, you may use any images you like providing that they are of the type specified by the problem description (*e.g.* 24-bit truecolor). Please do not use images that are obscene or gruesome. In general, an image is OK if you could show it to your grandmother without upsetting her or embarrassing yourself. A wide variety of images are available under creative commons license on the web site `www.flickr.com`. If you use one or more of these in your report, be sure to credit the photographer.

Note: In your report, group on the same page the images or pdfs that are to be compared so that it is easy to look from one to the other without having to jump around in the document.

Images to include in your report: Include the originals of any images that you used in the lab. Unless told otherwise, include all images that result from your processing. Sometimes you may not need to include the entire image but just a "nearest neighbor" enlarged section of it that shows the results more clearly than the entire image would. When that is required it will be in the instructions. Even if not asked for, you can include enlarged regions if that helps you to describe the results of processing.

Provide a photo credit for every image you use. That is, |em the first time you use an image in your report it must have a reference. That reference should include the name of the photographer, if it is available. Credit yourself if you took the picture. Include the source of the image, *e.g.* a URL. Use "personal collection" for your own images. If you know neither the photographer nor the source you should state that. There is no need to credit the same photo more than once.

Laboratory 3: Color Processing of Images

1. This problem explores the changes in color that occur when the individual bands of a true-color image are transformed independently of each other.

   Find a truecolor image that contains a wide range of colors. Use the gamma correction function you wrote for Lab Assignment 2 to increase and decrease the overall brightness of each band separately. Display the original image and the 6 altered versions. Describe the differences between the images. Here, I recommend that you cut the same small region out of the original and the 6 altered images so that you can display them all on the same page together. These need not be enlarged. See Figure 1.

Figure 1: Effects of increased and decreased gamma on the individual R, G, & B bands of a truecolor image. Left: Original image. Top L-R: Red $\gamma = 2$, Green $\gamma = 2$, Blue $\gamma = 2$. Bottom L-R: Red $\gamma = 1/4$, Green $\gamma = 1/4$, Blue $\gamma = 1/4$. Detail from a photograph by Jim Pyre: http://thedude.com/archives/2005/04/amsterdam.html.

2. Manipulation of HSV images.

    (a) Use the same image you used in problem 1. Convert the image to HSV using the `RGBtoHSV` function you wrote for Homework 3. Apply your gamma function to the V band, both to increase it and to decrease it. Reconstruct two new images using the altered V bands via your `HSVtoRGB` function. Include the results on the the same page of your report – either the full images or the same regions from both. Describe the results.

    (b) *Linearly* increase and *linearly* decrease the saturation. Reconstruct two new images using the altered S bands via your HSV-to-RGB function. Describe the results. Note that a linear increase may increase the value of the saturation of some pixels to > 1. You will need to clip the results at 1, prior to the conversion back to RGB. Include the results on the same page of your report – either the full images or the same regions from both. Describe the results.

    (c) Apply a constant circular shift to the H band to shift the colors in the green direction from hue $= 0$. Note that a circular shift of amount δ away from red toward green could cause the hues of some pixels to exceed 2π. These must be "wrapped around". That is, if $H(r, c) > 2\pi$ then replace $H(r, c)$ with $H(r, c) - 2\pi$. This can be done also with modulo 2π arithmetic.

    Repeat the same experiment but shift the colors in the blue direction. Note that you must perform an analogous wrapping to deal with the pixels whose hues are shifted to below zero in value.

    Reconstruct 2 new images using the altered H bands via your program `HSVtoRGB`. Include the results on the the same page of your report – either the full images or the same regions from both. Describe the results. How do these results differ from those of problem 1?

3. Correction of an image with a hue shift.

    Download the image.

    `PhotoDiskTestImageHueShifted.bmp`

    Download and read,

    `PhotoDiskTestImageReadMe.pdf`

    from the lab assignment 3 folder on Brightspace. The readme file contains information about the image. The image has been hue shifted into an unnatural color spectrum. Convert the image into HSV and try to shift it back into the correct color range. There are reference colors in the matrix of squares in the second row of objects. The row of colors just above the grayscale blocks are blue, green, red, yellow, magenta, and cyan. Include your estimate of the color shift in degrees from the correctly colored image to the discolored one. *E.g.* $d \in \{-\pi, \pi\}$ such that the hues in the discolored image were $d+$ the hues in the original image. Include the original, discolored image and the color corrected image in your report.

4. Correction of discolored photos through the linear transformation of color vectors.

   (a) Download the image,

       `AHS_Hotel_Comicon_667x1000_discolored.bmp`[1]

       from the lab assignment 3 folder on Brightspace. This image was derived from the original by multiplying each RGB pixel vector through a randomly generated 3x3 rigid rotation matrix. Select 6 (or more) different colors from the original image. That is, record the rgb values from at least 6 different pixel locations in the image. I suggest that you use the MATLAB function, `ginput`, for that purpose.

       To restore the image you will have to estimate what the original colors were. Here are some hints:

       - Ms. Bassett's blouse is a highly saturated yellow. Her jeans are blue.
       - Mr. Peters' shirt is nearly black with a slight magenta tint.
       - Ms. Paulson's blouse is white with an almost imperceptible magenta cast.
       - Ms. Bates' scarf background is a very slightly desaturated bright red.
       - Mr. Bomers' shirt's light stripes are nearly middle gray with a slight cyan tint.
       - The "COMICCON" lettering is a slightly desaturated yellow (darker than Ms. Bassett's blouse.)
       - The bacground surrounding the eye in the ComicCon logo is sky blue.

       Make a table that lists the pixel locations and the corresponding rgb triplets from the image and the colors you chose to map to them.

   (b) Construct a linear transformation matrix from the selected colors. Refer to slides 45-73 of the `Color Correction` lecture. List the transform matrix.

   (c) Transform the altered image using the transformation matrix. Display the original and the result, plot their pdfs, and comment on the differences between the two images.

5. Additional problem for graduate students.

   Please download and read the paper `Pascale - A review of RGB color spaces.pdf`.

   You may limit your reading of it to the parts that pertain to this problem.

   In Homework 3 you wrote a program that accepts an arbitrary RGB image I, converts the image into X, Y, and Z bands and outputs them. *E.g.*

```
>> [X,Y,Z] = RGBtoXYZ( I, M );
```

[1] Albert L. Ortega Getty Images, Partial cast of *American Horror Story: Hotel.* L-R: Angela Bassett, Evan Peters, Sarah Paulson, Kathy Bates, Matt Bomer at Comicon 2015

M, X, Y, and Z are of type double. I is of type uint8. And you wrote a program that computes the inverse,

```
>> J = XYZtoRGB( X, Y, Z, M );
```

where J is uint8.

Write a program that converts X, Y, and Z bands with one illuminant, v_s, to X, Y, and Z bands with another illuminant, v_d. You will need to construct a Bradford Matrix as shown on p. 16.

```
>> [X,Y,Z] = XYZtoXYZ( Xsrc, Ysrc, Zsrc, vsrc, vdst );
```

Write two programs, one that converts X, Y, Z, and v into L^*, a^*, and b^* bands, the other that computes the inverse.

```
>> [L,a,b] = XYZtoLab( X, Y, Z, v );
>> [X,Y,Z] = LabtoXYZ( L, a, b, v );
```

Verify that these two programs are inverses by using the same $9 \times 9 \times 3$ block from the X, Y, and Z bands that you generated from your RGB image.

Determine the natures of the L^*, a^*, and b^* bands by performing some experiments as follows:

Find a richly colored RGB image and convert it into L^*, a^*, and b^* bands using your programs, `RGBtoXYZ` and `XYZtoLab`. Indicate which M and v you used, and why you selected them. Then perform some point operations on the L band. Reconvert the resultant L^*s, and the original a^*, and b^* bands into RGB images using `LabtoXYZ` and `XYZtoRGB`. Do other (or the same) point operations on the a^* band alone, and an others on the b^* band alone and reconstruct the results. The goal is to determine the information carried in each of these bands. Use the original image and a subset (at least one for each band) of your modified RGB images to support your explanations.

Rules for laboratory assignments

1. Perform all the tasks listed in the instructions.
2. Explain the tasks you performed in detail.
3. Answer in writing in your report all the questions asked in the instructions.
4. Include in the report the original images you used and those resultant images that were specified in the instructions.
5. Include all computer code that you wrote and used, clearly documented, in an appendix.
6. All work must be yours and yours alone. Collaboration on the laboratory assignments is forbidden, with the following exceptions:
   (a) You may obtain help on any aspect of the homework from either Prof. Peters or the TA for this course.
   (b) You may obtain technical help on MATLAB from anyone you wish. However *you may not get direct help on the implementation of the specific algorithm* from another person except as noted in (a) above.
   (c) You may get help in obtaining the *input* images for the assignments from anyone you wish.
   (d) You may get help in the formatting or storing or transmission of your reports, but *not the content*, from anyone you wish.
7. Write your results in a clear laboratory report format using MS Word, WordPerfect, LaTeX, or any other word processor with which you can embed images in text. I prefer that the reports be submitted in .pdf format, but that is not required. Submit your report to me as a file on Brightspace. If for some reason this does not work, you may submit your report on a CD-ROM.
8. Assignments are due at midnight on the day specified in the instructions or in class. The grade on a laboratory report will be reduced by 10 points (out of 100) for every day (24 hours) that it is late.