Project 4 Report

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Contents

Step 2: Modified ref2XYZ Function

```
function [XYZ] = ref2XYZ(ref,cmfs,ill)
    k = 100./(cmfs(:,2)'*ill);
    XYZ = k.*cmfs'*diag(ill)*ref;
end
```

Step 3: Test Modified ref2XYZ Function

```
cie = loadCIEdata;
CC_spectra = load('ColorChecker_380-780-5nm.txt');
CC_XYZs = ref2XYZ(CC_spectra(:,2:25),cie.cmf2deg,cie.illD65)
```

```
CC_XYZs =

Columns 1 through 7

11.5145   39.1346   18.3488   11.1492   25.8437   31.7110   37.1457
10.3819   36.5981   19.6332   13.8551   24.3868   43.8600   29.5592
 7.1502   27.0564   35.6470    7.4267   45.6142   44.8778    6.5006

Columns 8 through 14

13.8627   29.1328    8.5889   33.9174   46.1864    8.9183   15.0353
12.3179   19.8475    6.4569   44.1533   42.4957    6.4177   24.1079
39.3093   14.9941   15.4745   11.4297    8.6771   32.2736    9.6379

Columns 15 through 21

%       19.3447   55.8457   29.6768   14.4138   87.8402   57.9621   35.2286
%   11.3576   58.9726   19.3515   19.9750   92.3781   61.0426   37.0414
%   5.5526    9.6411    32.2626   39.0008   95.6125   65.4909   40.2256
%
%   Columns 22 through 24
%
%   19.3492    8.7646    3.2111
%   20.4708    9.2915    3.3763
```

```
%   22.1545   10.3188    3.9312
%
```

Step 4: XYZ2Lab Function

```
function [Lab] = XYZ2Lab(XYZ,XYZn)

    Lab = zeros(size(XYZ));
    [r,c] = size(XYZ);

    for n = 1:c
        Lab(1,n) = 116*fofx(XYZ(2,n)/XYZn(2,1))-16;
        Lab(2,n) = 500*(...
            fofx(XYZ(1,n)/XYZn(1,1)) - ...
            fofx(XYZ(2,n)/XYZn(2,1))...
            );
        Lab(3,n) = 200*(...
            fofx(XYZ(2,n)/XYZn(2,1)) - ...
            fofx(XYZ(3,n)/XYZn(3,1))...
            );
    end
end

function [f] = fofx(x)
    if (x > 0.008856)
        f = x^(1/3);
    else
        f = 7.787 * x + 16/116;
    end
end
```

Step 5: Test XYZ2Lab Function

```
>> print_XYZ2Lab(false)

ColorChecker XYZ and Lab values (D65 illuminant and 2deg. observer)

Patch #    X       Y      Z       L*      a*      b*    Patch Nmae
   1  11.515  10.382  7.150  38.519  12.410  13.309  Dark Skin
   2  39.135  36.598  27.056  66.974  14.329  17.320  Light Skin
   3  18.349  19.633  35.647  51.420  -1.624  -21.603  Blue Sky
   4  11.149  13.855  7.427  44.024  -13.963  21.774  Foliage
   5  25.844  24.387  45.614  56.473  11.544  -24.698  Blue Flower
   6  31.711  43.860  44.878  72.135  -33.101  3.115  Bluish Green
   7  37.146  29.559  6.501  61.272  32.497  55.059  Orange
   8  13.863  12.318  39.309  41.717  14.416  -42.900  Purplish Blue
   9  29.133  19.847  14.994  51.664  45.468  13.382  Moderate Red
   10  8.589  6.457  15.474  30.537  23.785  -24.136  Purple
   11  33.917  44.153  11.430  72.331  -26.083  57.948  Yellow Green
   12  46.186  42.496  8.677  71.211  17.187  64.297  Orange Yellow
   13  8.918  6.418  32.274  30.443  27.024  -53.277  Blue
   14  15.035  24.108  9.638  56.196  -40.771  35.342  Green
   15  19.345  11.358  5.553  40.176  51.976  22.689  Red
   16  55.846  58.973  9.641  81.277  -0.508  78.575  Yellow
   17  29.677  19.352  32.263  51.096  50.004  -17.653  Magenta
   18  14.414  19.975  39.001  51.809  -25.642  -25.126  Cyan
   19  87.840  92.378  95.613  96.975  0.076  3.262  White
   20  57.962  61.043  65.491  82.402  -0.133  0.831  Neutral 8
   21  35.229  37.041  40.226  67.308  0.079  0.125  Neutral  6.5
   22  19.349  20.471  22.154  52.365  -0.541  0.237  Neutral 5
   23  8.765  9.291  10.319  36.540  -0.568  -0.600  Neutral 3.5
   24  3.211  3.376  3.931  21.492  0.035  -1.462  Black
```

Step 6: Modified ColorChecker Spectra Function

```
function print_XYZ2Lab(dark)
% load the CIE data into a structure
```

```
cie = loadCIEdata;

% compute the XYZ values of D65 for XYZn in XYZ2Lab
CC_spectra = load('ColorChecker_380-780-5nm.txt');

if (dark == true)
    CC_spectra = CC_spectra.*(.02);
end

CC_XYZs = ref2XYZ(CC_spectra(:,2:25),cie.cmf2deg,cie.illD65);

% compute the XYZ values of D65 for XYZn in XYZ2Lab
XYZn_D65 = ref2XYZ(cie.illE,cie.cmf2deg,cie.illD65);

% calculate the Lab values
CC_Labs = XYZ2Lab(CC_XYZs,XYZn_D65);

% read in the names of the ColorChecker patches
names = textread('ColorChecker_names.txt','%s','delimiter','|');

% print the formatted table
% header
if (not(dark))
    fprintf("ColorChecker XYZ and Lab values (D65 illuminant and 2"...
        + "deg. observer)\n");
    fprintf("Patch #    X       Y      Z       "...
        + "L*      a*      b*    Patch Nmae\n");
else
    fprintf("ColorChecker(Dark) XYZ and Lab values (D65 illuminant and 2"...
        + "deg. observer)\n");
    fprintf("Patch #   X      Y      Z      "...
        + "L*     a*     b*    Patch Nmae\n");
end

% loop to print the patch values
for n=1:size(CC_Labs,2)
    fprintf("      %i  %.3f  %.3f  %.3f  %.3f  %.3f  %.3f  %.3f  %s\n",...
        n,...
        CC_XYZs(1,n),...
        CC_XYZs(2,n),...
        CC_XYZs(3,n),...
        CC_Labs(1,n),...
        CC_Labs(2,n),...
        CC_Labs(3,n),...
        names{n}...
    );
end
```

Step 6: Test Modified ColorChecker Spectra

```
>> print_XYZ2Lab(true)

ColorChecker(Dark) XYZ and Lab values (D65 illuminant and 2deg.
observer)

Patch #   X      Y      Z      L*     a*     b*    Patch Nmae
   1  0.230  0.208  0.143  1.876  1.350  1.188  Dark Skin
   2  0.783  0.732  0.541  6.612  3.565  3.659  Light Skin
   3  0.367  0.393  0.713  3.547  -0.255  -4.082  Blue Sky
   4  0.223  0.277  0.149  2.503  -1.654  2.191  Foliage
   5  0.517  0.488  0.912  4.406  2.184  -5.453  Blue Flower
   6  0.634  0.877  0.898  7.924  -8.173  0.823  Bluish Green
   7  0.743  0.591  0.130  5.340  7.416  7.347  Orange
   8  0.277  0.246  0.786  2.225  1.766  -7.409  Purplish Blue
   9  0.583  0.397  0.300  3.586  8.414  1.893  Moderate Red
   10  0.172  0.129  0.309  1.166  2.009  -2.416  Purple
   11  0.678  0.883  0.229  7.977  -6.593  10.483  Yellow Green
```

```
   12  0.924  0.850  0.174  7.677  4.646  10.754  Orange Yellow
   13  0.178  0.128  0.645  1.159  2.309  -7.234  Blue
   14  0.301  0.482  0.193  4.355  -6.454  4.752  Green
   15  0.387  0.227  0.111  2.052  7.005  1.949  Red
   16  1.117  1.179  0.193  10.405  -0.138  15.181  Yellow
   17  0.594  0.387  0.645  3.496  9.246  -3.202  Magenta
   18  0.288  0.399  0.780  3.609  -3.745  -4.935  Cyan
   19  1.757  1.848  1.912  14.666  0.021  0.885  White
   20  1.159  1.221  1.310  10.710  -0.036  0.226  Neutral 8
   21  0.705  0.741  0.805  6.692  0.019  0.030  Neutral  6.5
   22  0.387  0.409  0.443  3.698  -0.088  0.038  Neutral 5
   23  0.175  0.186  0.206  1.679  -0.054  -0.058  Neutral 3.5
   24  0.064  0.068  0.079  0.610  0.002  -0.073  Black
```

Step 7: deltaEab Function

```
function [DEab] = deltaEab(Lab1,Lab2)

    [r, c] = size(Lab1);
    DEab = zeros(1,c);

    for n = 1:c
        DEab(1,n) = sqrt(...
            (Lab2(1,n) - Lab1(1,n))^(2) +...
            (Lab2(2,n) - Lab1(2,n))^(2) +...
            (Lab2(3,n) - Lab1(3,n))^(2)...
            );
    end

end
```

Step 8: Test deltaEab Function

```
ColorChecker and MetaChecker color differences

patch #  DEab(D65)  DEab(illA)
   1       2.597e-07        22.636
   2       1.136e-07        22.178
   3       1.056e-07        32.275
   4       1.905e-07        28.232
   5       3.980e-07        25.937
   6       1.326e-07        29.487
   7       8.581e-08        17.309
   8       1.454e-07        27.241
   9       1.665e-07        12.210
   10       2.907e-07        19.509
   11       1.561e-07        22.623
   12       1.305e-07        16.970
   13       1.083e-07        20.083
   14       1.193e-07        26.099
   15       6.708e-08        7.053
   16       1.330e-07        11.532
   17       6.468e-09        10.690
   18       8.581e-08        31.619
   19       2.661e-07        2.545
   20       6.948e-08        15.940
   21       1.846e-07        28.926
   22       8.337e-08        26.751
   23       3.668e-07        20.574
   24       1.022e-07        18.567
```

Step 9: Calculate CIELab Values and Color Differences Function

```
function [Color_Diff_Patches] = CIELab_patches(print)
% Use your XYZ2Lab and deltaEab functions to calculate CIELab values and
% color differences for your real, imaged and matching color patches.
```

```
XYZ_281 = load("Calculated_Patch_281_Tristimulus_Values.txt");
XYZ_282 = load("Calculated_Patch_282_Tristimulus_Values.txt");

XYZ_281_real = XYZ_281(:,1);
XYZ_281_imaged = XYZ_281(:,2);
XYZ_281_matching = XYZ_281(:,3);

XYZ_282_real = XYZ_282(:,1);
XYZ_282_imaged = XYZ_282(:,2);
XYZ_282_matching = XYZ_282(:,3);

% Calculate the CIELab values of your patches from the XYZ values.
% Reference illuminant XYZn should be D50

cie = loadCIEdata;
XYZn_D50 = ref2XYZ(cie.illE,cie.cmf2deg,cie.illD50);

Lab_281_real = XYZ2Lab(XYZ_281_real,XYZn_D50);
Lab_281_imaged = XYZ2Lab(XYZ_281_imaged,XYZn_D50);
Lab_281_matching = XYZ2Lab(XYZ_281_matching,XYZn_D50);

Lab_282_real = XYZ2Lab(XYZ_282_real,XYZn_D50);
Lab_282_imaged = XYZ2Lab(XYZ_282_imaged,XYZn_D50);
Lab_282_matching = XYZ2Lab(XYZ_282_matching,XYZn_D50);

% Calculate color differences between each of the real patches and their
% corresponding imaged and matched patches.

Eab_281_real_v_imaged = deltaEab(Lab_281_real,Lab_281_imaged);
Eab_281_real_v_matching = deltaEab(Lab_281_real,Lab_281_matching);

Eab_282_real_v_imaged = deltaEab(Lab_282_real,Lab_282_imaged);
Eab_282_real_v_matching = deltaEab(Lab_282_real,Lab_282_matching);

% Summarize the calculated XYZ and Lab values for your patches and the
% ?Eab color differences between the real patches and the corresponding
% imaged and matched patches.

if(print == true)
    disp("Calculated XYZ, Lab, deltaE values (w.r.t real patches)");

    fprintf("\n                                  patch 28.1");
    fprintf("\n       \t\t %s        %s        %s        %s        %s        %s        %s",...
        "X", "Y", "Z", "L", "a", "b", "dEab");
    fprintf("\n%s\t   %.3f   %.3f   %.3f   %.3f   %.3f   %.3f   %.3f",...
        "real",...
        XYZ_281_real',...
        Lab_281_real'...
        );
    fprintf("\n%s\t   %.3f   %.3f   %.3f   %.3f   %.3f   %.3f   %.3f",...
        "imaged",...
        XYZ_281_imaged',...
        Lab_281_imaged',...
        Eab_281_real_v_imaged...
        );
    fprintf("\n%s   %.3f   %.3f   %.3f   %.3f   %.3f   %.3f   %.3f",...
        "matching",...
        XYZ_281_matching',...
        Lab_281_matching',...
        Eab_281_real_v_matching...
        );


    fprintf("\n\n                                  patch 28.2");
    fprintf("\n       \t\t %s        %s        %s        %s        %s        %s        %s",...
        "X", "Y", "Z", "L", "a", "b", "dEab");
    fprintf("\n%s\t   %.3f   %.3f   %.3f   %.3f   %.3f   %.3f   %.3f",...
        "real",...
        XYZ_282_real',...
```

```
        Lab_282_real'...
        );
    fprintf("\n%s\t   %.3f   %.3f   %.3f   %.3f   %.3f   %.3f   %.3f",...
        "imaged",...
        XYZ_282_imaged',...
        Lab_282_imaged',...
        Eab_282_real_v_imaged...
        );
    fprintf("\n%s   %.3f   %.3f   %.3f   %.3f   %.3f   %.3f   %.3f\n\n",...
        "matching",...
        XYZ_282_matching',...
        Lab_282_matching',...
        Eab_282_real_v_matching...
        );

else
    % return color differences for graph
    Color_Diff_Patches = cat(1, cat(1, cat(2, Lab_281_real', 0), cat(2, Lab_281_imaged', Eab_281_real_v_imaged), cat(2, Lab_281_matching', Eab_281_real_v_matching)), cat(1, cat(2, Lab_282_real', 0), cat(2, Lab_282_imaged

end
```

Step 9: Test CIELab Values and Color Differences Function

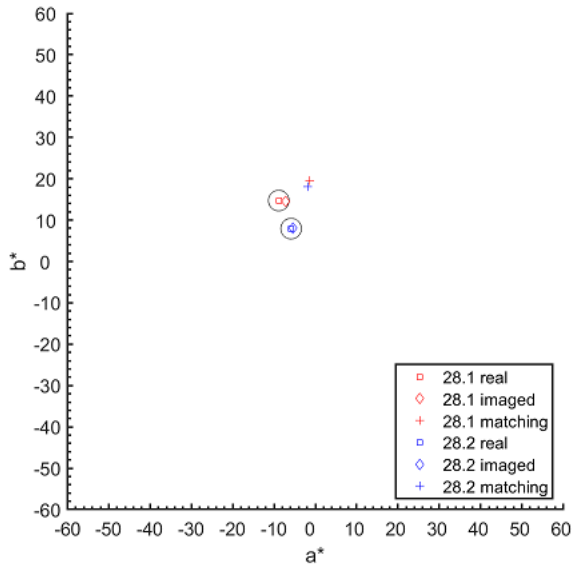
```
>> CIELab_patches(true)

Calculated XYZ, Lab, deltaE values (w.r.t real patches)

                            patch 28.1
                       X        Y        Z        L        a        b        dEab
 real      33.517   37.456   22.373   67.618   -8.855   14.727
 imaged    30.667   33.859   20.052   64.850   -7.190   14.596   3.232
 matching   40.523   42.502   23.109   71.216   -1.403   19.528   9.567

                            patch 28.2
                       X        Y        Z        L        a        b        dEab
 real      27.578   30.159   20.728   61.791   -5.870   7.935
 imaged    23.509   25.675   17.436   57.728   -5.429   7.999   4.088
 matching   29.547   31.169   16.721   62.650   -1.914   18.137   10.976
```

Step 10: Graphing Color Differences between Real, Imaged, and Matching Patches Function

```
function plot_color_diff
Color_Diff_Patches = CIELab_patches(false);

disp(Color_Diff_Patches);

% create a new figure with hold on and line_width = 1.5
figure;
hold on;
line_weight = 1.5;

set(gca, 'FontSize', 14);
set(gca, 'LineWidth', line_weight);
axis('equal'); % make plot scales equal
axis([-60,60,-60,60]); % set the axis ranges
xlabel('a*');
ylabel('b*');

% set the min and max for each axis of the plot
axis([-60 60 -60 60],'xy');

% force the tick spacing of the plot to be 0.3 on the X axis
set(gca, 'XTick', -60:10:60);
set(gca, 'XTickLabel', -60:10:60 );

% force the tick spacing of the plot to be 0.3 on the Y axis
```

```
set(gca, 'YTick', -60:10:60);
set(gca, 'YTickLabel', -60:10:60 );

% set the minor ticks on the axis
set(gca, 'XMinorTick', 'on');
set(gca, 'YMinorTick', 'on');


r1 = plot(Color_Diff_Patches(1,2),Color_Diff_Patches(1,3),'sr');
c1 = viscircles([Color_Diff_Patches(1,2) Color_Diff_Patches(1,3)],2.5,'Color','black', 'LineWidth', .5);
i1 = plot(Color_Diff_Patches(2,2),Color_Diff_Patches(2,3),'dr');
m1 = plot(Color_Diff_Patches(3,2),Color_Diff_Patches(3,3),'+r');
r2 = plot(Color_Diff_Patches(4,2),Color_Diff_Patches(4,3),'sb');
c2 = viscircles([Color_Diff_Patches(4,2) Color_Diff_Patches(4,3)],2.5,'Color','black', 'LineWidth', .5);
i2 = plot(Color_Diff_Patches(5,2),Color_Diff_Patches(5,3),'db');
m2 = plot(Color_Diff_Patches(6,2),Color_Diff_Patches(6,3),'+b');

legend([r1 i1 m1 r2 i2 m2],{'28.1 real','28.1 imaged','28.1 matching','28.2 real','28.2 imaged','28.2 matching'},'Location','southeast');


end
```

Step 10: Color Differences between Real, Imaged, and Matching Patches Graph



Step 11: Feedback

Who did what parts of the project

- Kevin - Step 2
- Kevin - Step 3
- Kevin - Step 4
- Kevin - Step 5
- Kevin - Step 6
- Kevin - Step 7

- Molly - Step 8
- Molly - Step 9
- Molly - Step 10
- Molly - Step 11

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