Credits

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Contents

Initialization

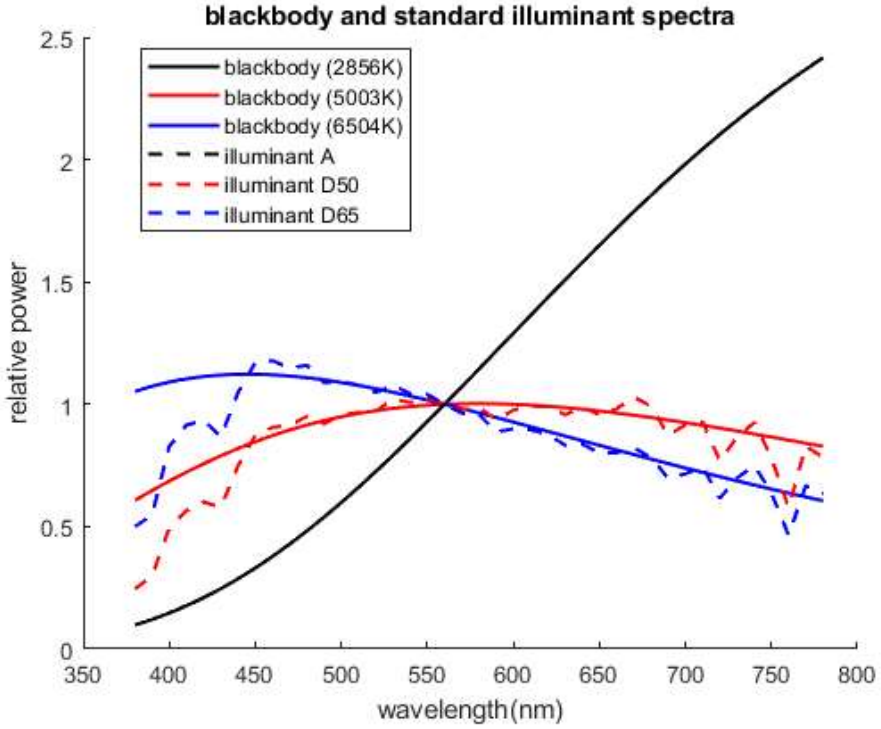
```
clear
cie = loadCIEdata;
```

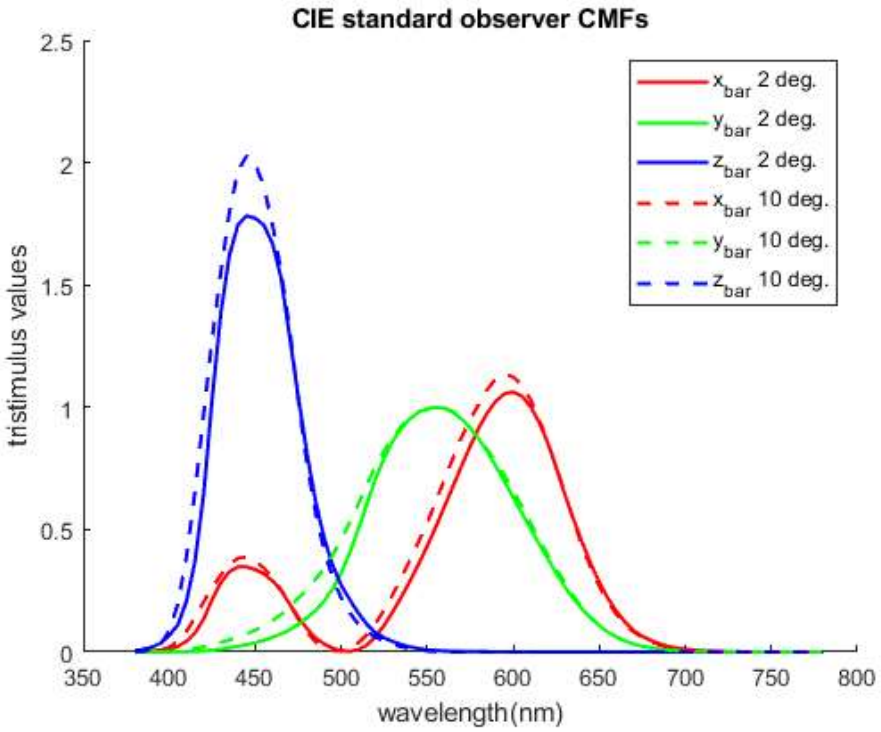
Project 3 - Step 3

Blackbody and CIE Standard Observer -Data

```
BB2856K = blackbody(2856, cie.lambda); %Illuminant A's   BB
BB5003K = blackbody(5003, cie.lambda); %Illuminant D50's BB
BB6504K = blackbody(6504, cie.lambda); %Illuminant D65's BB

% Find value to normalize
index = 37; %Index of the 560nm
ANormVal = cie.illA(index, 1);
D50NormVal = cie.illD50(index, 1);
D65NormVal = cie.illD65(index, 1);

% Normalize
illANormalized = cie.illA./ANormVal;
illD50Normalized = cie.illD50./D50NormVal;
illD65Normalized = cie.illD65./D65NormVal;

% Blackbody and CIE Standard Observer -Graphs
% x-axis
cie.lambda;

% Plot -> Blackbody
figure(1);
hold on
plot(cie.lambda,BB2856K,'Color',[0,0,0],'LineWidth',1.5)
plot(cie.lambda,BB5003K,'Color',[1,0,0],'LineWidth',1.5)
plot(cie.lambda,BB6504K,'Color',[0,0,1],'LineWidth',1.5)

% Plot -> Standard Illuminants
plot(cie.lambda, illANormalized,  'Color',[0,0,0],'LineWidth',1.5,'LineStyle','--');
plot(cie.lambda, illD50Normalized,'Color',[1,0,0],'LineWidth',1.5,'LineStyle','--');
plot(cie.lambda, illD65Normalized,'Color',[0,0,1],'LineWidth',1.5,'LineStyle','--');
```

```
hold off

% Format plot(s)
title('blackbody and standard illuminant spectra')
xlabel('wavelength(nm)')
ylabel('relative power')
xlim([350 800]);
ylim([0 2.5]);
legend('Location', 'best') %Auto-places Legend
legend('blackbody (2856K)','blackbody (5003K)', 'blackbody (6504K)', ...
       'illuminant A', 'illuminant D50', 'illuminant D65');

% Plot -> 2-Degree
figure(2);
hold on
plot(cie.lambda,cie.cmf2deg(:,1),'Color',[1,0,0],'LineWidth',1.5)
plot(cie.lambda,cie.cmf2deg(:,2),'Color',[0,1,0],'LineWidth',1.5)
plot(cie.lambda,cie.cmf2deg(:,3),'Color',[0,0,1],'LineWidth',1.5)

% Plot -> 10-Degree
plot(cie.lambda,cie.cmf10deg(:,1),'Color',[1,0,0],'LineWidth',1.5,'LineStyle','--')
plot(cie.lambda,cie.cmf10deg(:,2),'Color',[0,1,0],'LineWidth',1.5,'LineStyle','--')
plot(cie.lambda,cie.cmf10deg(:,3),'Color',[0,0,1],'LineWidth',1.5,'LineStyle','--')
hold off

% Format plot(s)
title('CIE standard observer CMFs')
xlabel('wavelength(nm)')
ylabel('tristimulus values')
xlim([350 800]);
ylim([0 2.5]);
legend('x_b_a_r 2 deg.','y_b_a_r 2 deg.', 'z_b_a_r 2 deg.', ...
       'x_b_a_r 10 deg.', 'y_b_a_r 10 deg.', 'z_b_a_r 10 deg.');
```





Project 3 - Step 4

This function takes Surface reflectance, Color Matching Function, Illumination and converts it to XYZ tristimulus values. refs = Surface reflectance nx1 vector

```
cmfs = Color matching functions nx3 vector
       in [x,y,z] order

illum = SPD of light source nx1 vector

%%
% This function takes Surface reflectance, Color Matching Function, Illumination and converts it to XYZ tristimulus values.
```

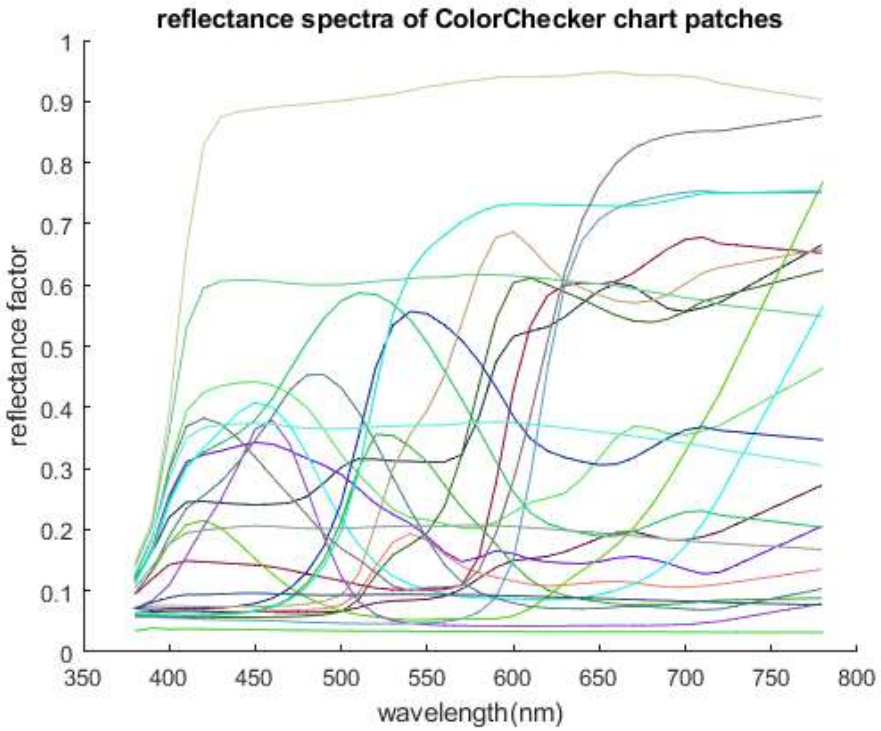
```
%   refs = Surface reflectance nx1 vector
%
%   cmfs = Color matching functions nx3 vector
%          in [x,y,z] order
%
%   illum = SPD of light source nx1 vector
%
% <include>ref2XYZ.m</include>

%                     R(λ)  x,y,z  S(λ)
function XYZ = ref2XYZ(refs, cmfs,  illum)
k = 100 / sum(cmfs(:, 2).*illum);
X = k * sum(cmfs(:, 1).*illum.*refs);
Y = k * sum(cmfs(:, 2).*illum.*refs);
Z = k * sum(cmfs(:, 3).*illum.*refs);
XYZ = [X,Y,Z];
end
```

Project 3 - Step 5

```
CC_spectra = importdata('ColorChecker_380_780_5nm.txt');
for patch_num = 2:25
CC_XYZs(:,patch_num-1) = ref2XYZ(CC_spectra(:,patch_num),cie.cmf2deg,cie.illD65);
end
CC_XYZs

% Plot ColorChecker
figure(3)
hold on
for patch = 1:size(CC_spectra, 2)-1
    plot(cie.lambda, CC_spectra(:, patch +1), 'Color',rand(1,3))
end

% Format Plot
title('reflectance spectra of ColorChecker chart patches')
xlabel('wavelength(nm)')
ylabel('reflectance factor')
xlim([350 800]);
ylim([0 1]);
hold off
```

```
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
```



Project 3 - Step 6

This function takes an input XYZ - 3xn vector and returns xyY - 3xn vector - chromaticity coordinates XYZ = trustimulus values, vector

```
x,y = chromaticity coordinates, vector

Y = Luminance factor
```

```
%%
% This function takes an input XYZ - 3xn vector
% and returns xyY - 3xn vector - chromaticity coordinates
%   XYZ = trustimulus values, vector
%
%   x,y = chromaticity coordinates, vector
%
%   Y = Luminance factor
%
% <include>XYZ2xyY.m</include>

function xyY = XYZ2xyY(XYZ)
X = XYZ(1, :);
Y = XYZ(2, :);
Z = XYZ(3, :);

x = X ./ (X+Y+Z);
y = Y ./ (X+Y+Z);

xyY = [x;y;Y];
end
```

Project 3 - Step 7

```
CC_xyYs = XYZ2xyY(CC_XYZs);
CC_xyYs

% Lab 3 - Step 8
cm_lams=380:10:730;
cm_h_offset = 19;
% Import Data and Normalize to 1 - Patch 5.1
data=importdata('5.1_real.sp', ' ', cm_h_offset);
patch1.real = data.data/100;
cm_h_offset = 18;
data=importdata('5.1_imaged.sp', ' ', cm_h_offset);
patch1.imaged = data.data/100;
data=importdata('5.1_matching.sp', ' ', cm_h_offset);
patch1.matching = data.data/100;

% Import Data and Normalize to 1 - Patch 5.2
cm_h_offset = 19;
data=importdata('5.2_real.sp', ' ', cm_h_offset);
patch2.real = data.data/100;
cm_h_offset = 18;
data=importdata('5.2_imaged.sp', ' ', cm_h_offset);
patch2.imaged = data.data/100;
data=importdata('5.2_matching.sp', ' ', cm_h_offset);
patch2.matching = data.data/100;
```

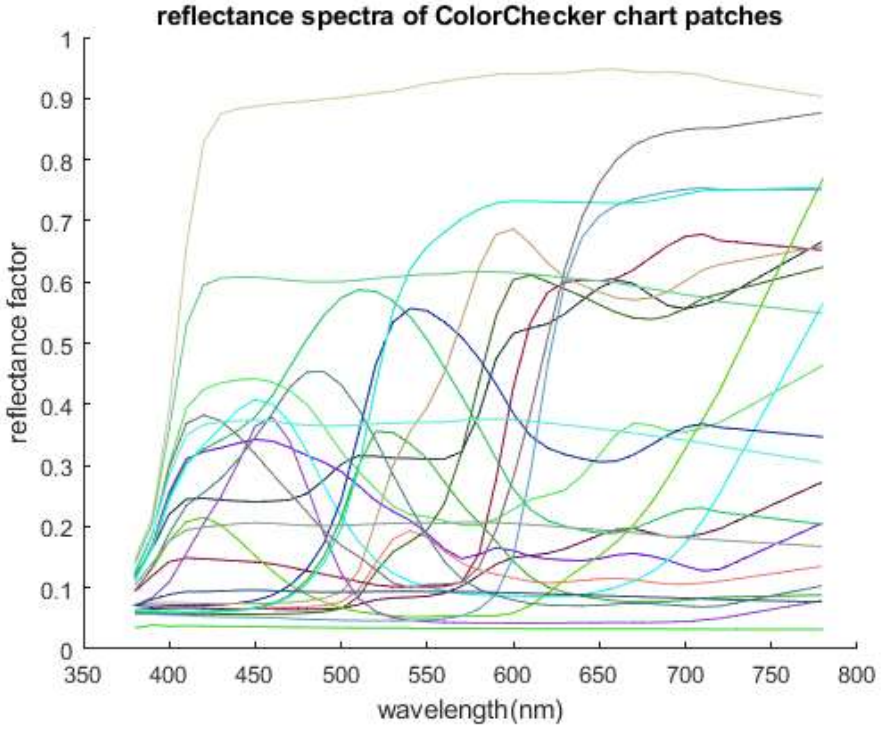
```
CC_xyYs =

  Columns 1 through 7

    0.3964    0.3807    0.2492    0.3438    0.2696    0.2633    0.5074
    0.3574    0.3561    0.2667    0.4272    0.2544    0.3641    0.4038
   10.3819   36.5981   19.6332   13.8551   24.3868   43.8600   29.5592

  Columns 8 through 14

    0.2117    0.4554    0.2814    0.3790    0.4744    0.1873    0.3082
    0.1881    0.3102    0.2116    0.4933    0.4365    0.1348    0.4942
   12.3179   19.8475    6.4569   44.1533   42.4957    6.4177   24.1079

  Columns 15 through 21

    0.5336    0.4487    0.3651    0.1964    0.3185    0.3142    0.3132
    0.3133    0.4738    0.2381    0.2722    0.3349    0.3309    0.3293
   11.3576   58.9726   19.3515   19.9750   92.3781   61.0426   37.0414

  Columns 22 through 24

    0.3122    0.3089    0.3053
    0.3303    0.3275    0.3210
   20.4708    9.2915    3.3763
```

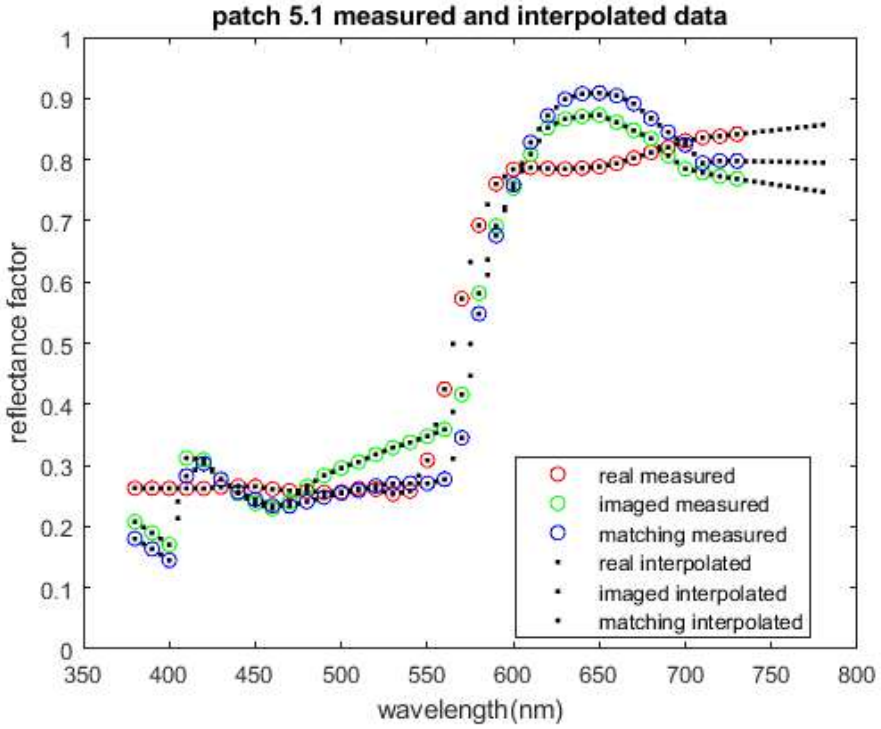
Project 3 - Step 9

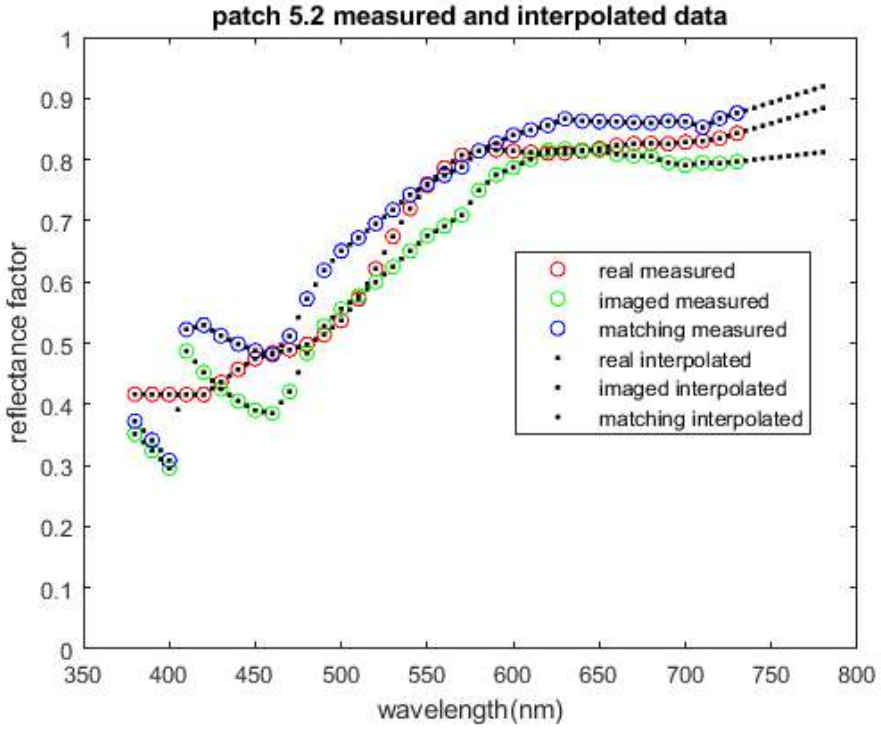
Interpolation of Patch data

```
patch1.Ireal=interp1(cm_lams,patch1.real, cie.lambda(:), "linear", "extrap");
patch1.Iimaged=interp1(cm_lams,patch1.imaged,cie.lambda(:), "linear", "extrap");
patch1.Imatching=interp1(cm_lams,patch1.matching, cie.lambda(:), "linear", "extrap");
patch2.Ireal=interp1(cm_lams,patch2.real, cie.lambda(:), "linear", "extrap");
```

```
patch2.Iimaged=interp1(cm_lams,patch2.imaged,cie.lambda(:), "linear", "extrap");
patch2.Imatching=interp1(cm_lams,patch2.matching, cie.lambda(:), "linear", "extrap");

% Plot Figure 4
figure(4)
plot(cm_lams, patch1.real, 'o', 'Color', [1,0,0]);
hold on
plot(cm_lams, patch1.imaged,'o', 'Color', [0,1,0]);
plot(cm_lams, patch1.matching,'o', 'Color', [0,0,1]);
plot(cie.lambda,patch1.Ireal,'.', 'Color', [0,0,0]);
plot(cie.lambda,patch1.Iimaged,'.', 'Color', [0,0,0]);
plot(cie.lambda,patch1.Imatching,'.', 'Color', [0,0,0]);

% Format plot
title('patch 5.1 measured and interpolated data')
legend('real measured', 'imaged measured', 'matching measured', ...
    'real interpolated', 'imaged interpolated', 'matching interpolated', 'Location','best');
xlabel('wavelength(nm)')
ylabel('reflectance factor')
xlim([350 800]);
ylim([0 1]);
hold off

% Plot Figure 5
figure(5)
plot(cm_lams, patch2.real,'o', 'Color', [1,0,0]);
hold on
plot(cm_lams, patch2.imaged,'o', 'Color', [0,1,0]);
plot(cm_lams, patch2.matching,'o', 'Color', [0,0,1]);
plot(cie.lambda,patch2.Ireal,'.', 'Color', [0,0,0]);
plot(cie.lambda,patch2.Iimaged,'.', 'Color', [0,0,0]);
plot(cie.lambda,patch2.Imatching,'.', 'Color', [0,0,0]);
hold off

% Format Plot
title('patch 5.2 measured and interpolated data')
legend('real measured', 'imaged measured', 'matching measured', ...
    'real interpolated', 'imaged interpolated', 'matching interpolated', 'Location','best');
xlabel('wavelength(nm)')
ylabel('reflectance factor')
xlim([350 800]);
ylim([0 1]);
hold off
```


reflectance spectra of ColorChecker chart patches
reflectance factor
wavelength(nm)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
350
400
450
500
550
600
650
700
750
800


patch 5.1 measured and interpolated data
reflectance factor
wavelength(nm)
real measured
imaged measured
matching measured
real interpolated
imaged interpolated
matching interpolated
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
350
400
450
500
550
600
650
700
750
800



Project 3 - Step 10

```
%Calculated values for XYZ Patch 1
patch1.CalcrealXYZ = ref2XYZ(patch1.Ireal, cie.cmf2deg, cie.illD50);
patch1.CalcimagedXYZ = ref2XYZ(patch1.Iimaged, cie.cmf2deg, cie.illD50);
patch1.CalcmatchingXYZ = ref2XYZ(patch1.Imatching, cie.cmf2deg, cie.illD50);
%Calculated values for XYZ Patch 2
patch2.CalcrealXYZ = ref2XYZ(patch2.Ireal, cie.cmf2deg, cie.illD50);
patch2.CalcimagedXYZ = ref2XYZ(patch2.Iimaged, cie.cmf2deg, cie.illD50);
patch2.CalcmatchingXYZ = ref2XYZ(patch2.Imatching, cie.cmf2deg, cie.illD50);
%Reading in the ColorMunki XYZ data and assiging to struct
real_measuredXYZ = readmatrix('5_XYZ_Labs_Real.txt');
imaged_measuredXYZ = readmatrix('5_XYZ_Labs_imaged.txt');
matching_measuredXYZ = readmatrix('5_XYZ_Labs_matching.txt');

%Patch 1
patch1.CMreal = real_measuredXYZ(1,2:4);
patch1.CMimaged = imaged_measuredXYZ(1,2:4);
patch1.CMmatching = matching_measuredXYZ(1,2:4);
%Patch 2
patch2.CMreal = real_measuredXYZ(2,2:4);
patch2.CMimaged = imaged_measuredXYZ(2,2:4);
patch2.CMmatching = matching_measuredXYZ(2,2:4);

%Table 1 -Header
fprintf('%s\n\n',"Measured and calculated tristumulus values");
fprintf('%48s\n', "patch 5.1");
fprintf('%30s %37s\n', "measured", "calculated");
fprintf('%14s %12s %10s %12s %12s %10s\n', "X", "Y", "Z", "X", "Y", "Z");

%Table 2 -Data
fprintf('%8s %2.6f   %2.6f   %2.6f %s', 'real',patch1.CMreal, '    ');
fprintf('%2.6f   %2.6f   %2.6f\n', patch1.CalcrealXYZ);
fprintf('%8s %2.6f   %2.6f   %2.6f %s', 'imaged', patch1.CMimaged, '    ');
fprintf('%2.6f   %2.6f   %2.6f\n', patch1.CalcimagedXYZ);
fprintf('%8s %2.6f   %2.6f   %2.6f %s', 'matching', patch1.CMmatching,'    ');
fprintf('%2.6f   %2.6f   %2.6f\n\n\n', patch1.CalcmatchingXYZ);
```

```
%Table 2 -Header
fprintf('%48s\n', "patch 5.2");
fprintf('%30s %37s\n', "measured", "calculated");
fprintf('%14s %12s %10s %12s %12s %10s\n', "X", "Y", "Z", "X", "Y", "Z");

%Tabel 2 -Data
fprintf('%8s %2.6f   %2.6f   %2.6f %s', 'real',patch2.CMreal, '   ');
fprintf('%2.6f   %2.6f   %2.6f\n', patch2.CalcrealXYZ);
fprintf('%8s %2.6f   %2.6f   %2.6f %s', 'imaged', patch2.CMimaged, '   ');
fprintf('%2.6f   %2.6f   %2.6f\n', patch2.CalcimagedXYZ);
fprintf('%8s %2.6f   %2.6f   %2.6f %s', 'matching', patch2.CMmatching,'   ');
fprintf('%2.6f   %2.6f   %2.6f\n\n\n', patch2.CalcmatchingXYZ);
```

```
Measured and calculated tristumulus values

                                patch 5.1
                    measured                            calculated
             X           Y          Z           X           Y          Z
    real 59.568041   48.408812   21.659977   59.521056   48.423787   21.663595
  imaged 58.532704   48.103032   21.160113   58.506612   48.124684   21.184821
matching 57.439869   44.116577   20.622835   57.410502   44.149359   20.631810


                                patch 5.2
                    measured                            calculated
             X           Y          Z           X           Y          Z
    real 72.815908   73.733772   39.540661   72.794989   73.713088   39.552705
  imaged 68.952098   68.919208   35.522153   68.941246   68.910134   35.571275
matching 75.138289   76.509450   43.053816   75.128645   76.498828   43.091674
```

Project 3 - Step 11

```
%CMunki xyY patch 1
patch1.CMrealxyY=XYZ2xyY(patch1.CMreal');
patch1.CMimagedxyY = XYZ2xyY(patch1.CMimaged');
patch1.CMmatchingxyY = XYZ2xyY(patch1.CMmatching');
%CMunki xyY patch 2
patch2.CMrealxyY=XYZ2xyY(patch2.CMreal');
patch2.CMimagedxyY = XYZ2xyY(patch2.CMimaged');
patch2.CMmatchingxyY = XYZ2xyY(patch2.CMmatching');
%Calculated xyY patch 1
patch1.CalcrealxyY = XYZ2xyY(patch1.CalcrealXYZ');
patch1.CalcimagedxyY = XYZ2xyY(patch1.CalcimagedXYZ');
patch1.CalcmatchingxyY = XYZ2xyY(patch1.CalcmatchingXYZ');
%Calculated xyY patch 2
patch2.CalcrealxyY = XYZ2xyY(patch2.CalcrealXYZ');
patch2.CalcimagedxyY = XYZ2xyY(patch2.CalcimagedXYZ');
patch2.CalcmatchingxyY = XYZ2xyY(patch2.CalcmatchingXYZ');

% Table 1 -Header
fprintf('%s\n\n',"Measured and calculated tristumulus values");
fprintf('%48s\n', "patch 5.1");
fprintf('%30s %37s\n', "measured", "calculated");
fprintf('%13s %12s %10s %10s %12s %10s\n', "x", "y", 'Y', 'x', 'y', 'Y');

%Table 1 -Data
fprintf('%8s %2.6f   %2.6f   %2.6f %s', 'real', patch1.CMrealxyY, '   ');
fprintf('%2.6f   %2.6f   %2.6f\n', patch1.CalcrealxyY);
fprintf('%8s %2.6f   %2.6f   %2.6f %s', 'imaged', patch1.CMimagedxyY, '   ');
fprintf('%2.6f   %2.6f   %2.6f\n', patch1.CalcimagedxyY);
```

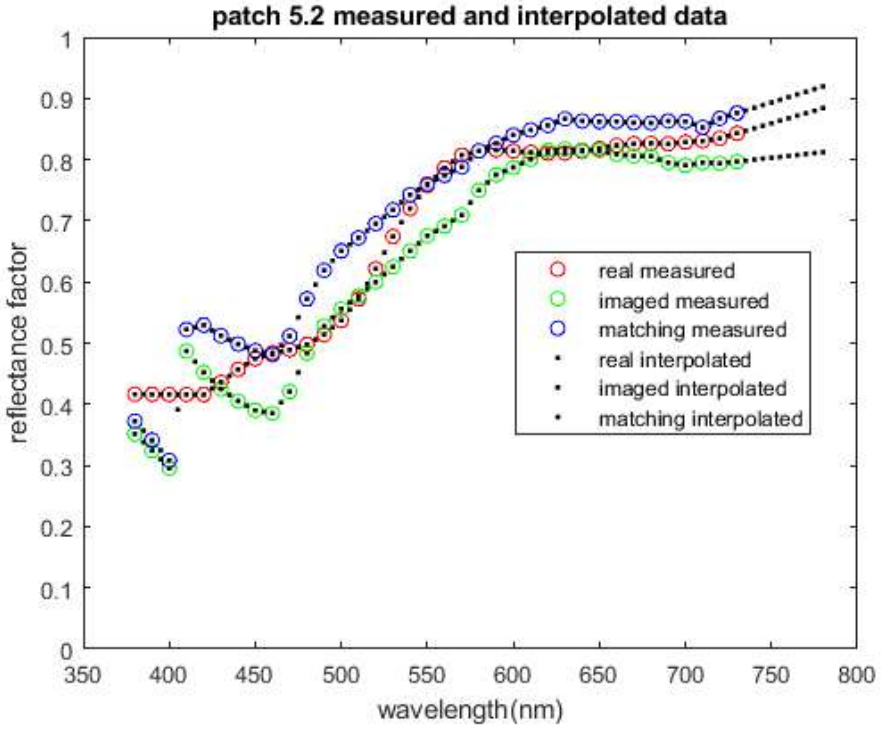
```
fprintf('%8s %2.6f   %2.6f   %2.6f %s', 'matching', patch1.CMmatchingxyY,'   ');
fprintf('%2.6f   %2.6f   %2.6f\n\n\n', patch1.CalcmatchingxyY);

%Table 2 -Header
fprintf('%48s\n', "patch 5.2");
fprintf('%30s %37s\n', "measured", "calculated");
fprintf('%13s %12s %10s %10s %12s %10s\n', "x", "y", 'Y', 'x', 'y', 'Y');

%Table 2 -Data
fprintf('%8s %2.6f   %2.6f   %2.6f %s', 'real', patch2.CMrealxyY, '   ');
fprintf('%2.6f   %2.6f   %2.6f\n', patch2.CalcrealxyY);
fprintf('%8s %2.6f   %2.6f   %2.6f %s', 'imaged', patch2.CMimagedxyY, '   ');
fprintf('%2.6f   %2.6f   %2.6f\n', patch2.CalcimagedxyY);
fprintf('%8s %2.6f   %2.6f   %2.6f %s', 'matching', patch2.CMmatchingxyY,'   ');
fprintf('%2.6f   %2.6f   %2.6f\n\n\n', patch2.CalcmatchingxyY);
```

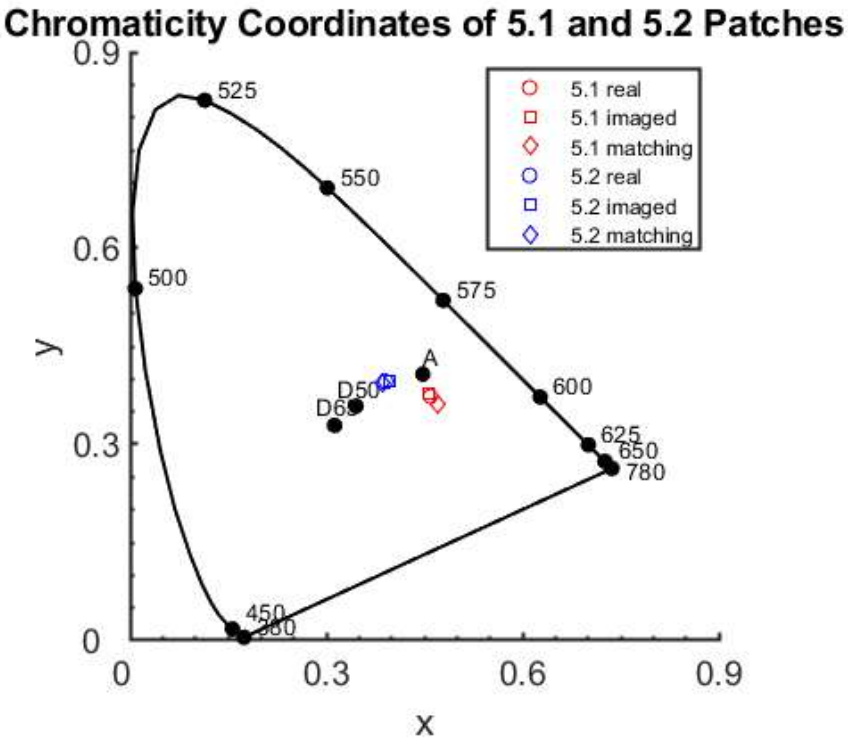
```
Measured and calculated tristumulus values

                                  patch 5.1
                     measured                            calculated
           x           y          Y          x           y          Y
    real 0.459499   0.373419   48.408812    0.459238   0.373616   48.423787
  imaged 0.458017   0.376405   48.103032    0.457740   0.376515   48.124684
matching 0.470128   0.361081   44.116577    0.469840   0.361312   44.149359


                                  patch 5.2
                     measured                            calculated
           x           y          Y          x           y          Y
    real 0.391293   0.396226   73.733772    0.391243   0.396177   73.713088
  imaged 0.397663   0.397473   68.919208    0.397533   0.397354   68.910134
matching 0.385915   0.392958   76.509450    0.385831   0.392868   76.498828
```

Project 3 - Step 12

Plot chromaticity skeleton

```
plot_chrom_diag_skel;

% Plot Patch 1
plot(patch1.CalcrealxyY(1,1),patch1.CalcrealxyY(2,1),'o','Color', [1,0,0], 'DisplayName', '5.1 real');
plot(patch1.CalcimagedxyY(1,1),patch1.CalcimagedxyY(2,1),'square','Color', [1,0,0], 'DisplayName', '5.1 imaged');
plot(patch1.CalcmatchingxyY(1,1),patch1.CalcmatchingxyY(2,1),'diamond','Color', [1,0,0], 'DisplayName', '5.1 matching');


% Plot Patch 2
plot(patch2.CalcrealxyY(1,1),patch2.CalcrealxyY(2,1),'o','Color', [0,0,1], 'DisplayName', '5.2 real');
plot(patch2.CalcimagedxyY(1,1),patch2.CalcimagedxyY(2,1),'square','Color', [0,0,1], 'DisplayName', '5.2 imaged');
plot(patch2.CalcmatchingxyY(1,1),patch2.CalcmatchingxyY(2,1),'diamond','Color', [0,0,1],'DisplayName', '5.2 imaged');

% Format Plot
title('Chromaticity Coordinates of 5.1 and 5.2 Patches')
legend({'', '', '','','','','','','','','','','','','', ...
        '5.1 real', '5.1 imaged', '5.1 matching', ...
        '5.2 real', '5.2 imaged', '5.2 matching'}, ...
        'Location', 'northeast', 'FontSize',9)
```





Feedback

```
% i.)
% Cooper and Gian-Mateo both coded the project; Cooper and Gian-Mateo spend
% several adruous hours debugging together

% ii.)
% We had to reference google for some fprintf tips, and for formatting the
% shapes of the points in our plots for interpolated vs real data.

%iii.)
%Structs were QUITE valuable as it made our workspace more streamlined, and
```

```
%cut down on confusing variable notation

%iv.)
% no improvments needed, just took a while, and caffeine
```

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