Project 3 Report

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Contents

start clean

```
clear all; close all; clc;
```

step 2a

```
% load the CIE observer and illuminant data
cie = loadCIEdata;
```

step 2b

Include listing of loadCIEdata

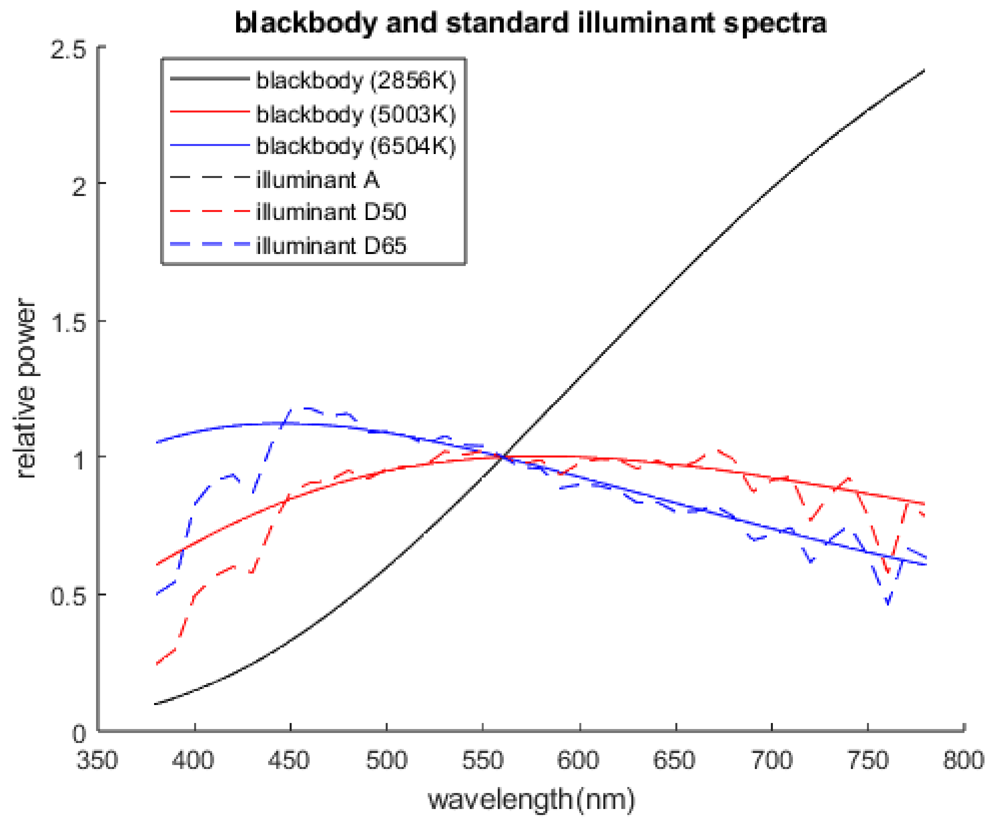
```
function [cie] = loadCIEdata
    data2deg = load('../color_toolbox/CIE_2Deg_380-780-5nm.txt');
    cie.lambda = data2deg(:, 1);        % Wavelengths (81x1 column vector)
    cie.cmf2deg = data2deg(:, 2:4);     % 2-degree CMF (81x3 array)

    data10deg = load('../color_toolbox/CIE_10Deg_380-780-5nm.txt');
    cie.cmf10deg = data10deg(:, 2:4);   % 10-degree CMF (81x3 array)

    dataIllA = load('../color_toolbox/CIE_IllA_380-780-5nm.txt');
    cie.illA = dataIllA(:, 2);          % Illuminant A (81x1 column vector)

    dataIllC = load('../color_toolbox/CIE_IllC_380-780-5nm.txt');
    cie.illC = dataIllC(:, 2);          % Illuminant C (81x1 column vector)
```

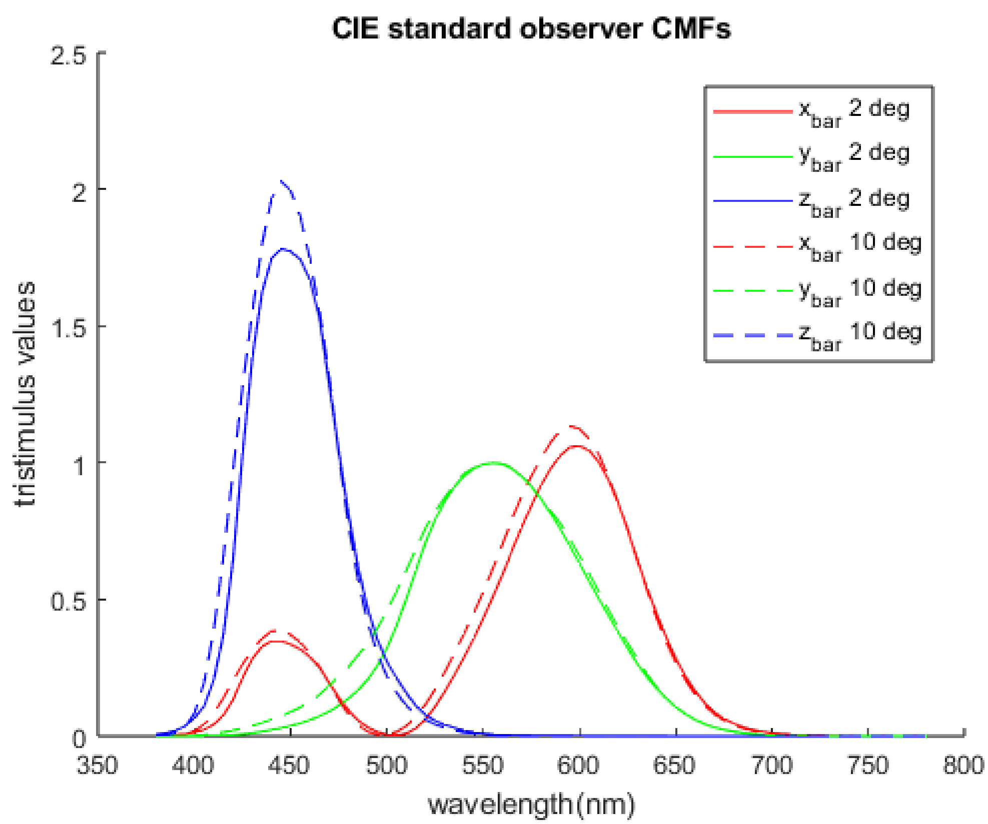
```
    dataIllD50 = load('../color_toolbox/CIE_IllD50_380-780-5nm.txt');
    cie.illD50 = dataIllD50(:, 2);      % Illuminant D50 (81x1 column vector)

    dataIllD65 = load('../color_toolbox/CIE_IllD65_380-780-5nm.txt');
    cie.illD65 = dataIllD65(:, 2);      % Illuminant D65 (81x1 column vector)

    % Create illuminant E with a constant value of 100
    cie.illE = 100 * ones(81, 1);       % Illuminant E (81x1 column vector)

    dataIllF = load('../color_toolbox/CIE_IllF_1-12_380-780-5nm.txt');
    cie.illF = dataIllF(:, 2:end);      % Illuminant F1-F12 (81x12 array)

    % Create PRD with a constant value of 1
    cie.PRD = ones(81, 1);              % PRD (81x1 column vector)
end
```

step 3

test loadCIEdata by ploting illA, D50, and D65 vs. the blackbody curves

```
bb_2856 = blackbody(2856,cie.lambda);
bb_5003 = blackbody(5003,cie.lambda);
bb_6504 = blackbody(6504,cie.lambda);

figure(1);
hold on;

plot(cie.lambda,bb_2856,'k', cie.lambda,bb_5003,'r', cie.lambda,bb_6504,'b', ...
    cie.lambda,(cie.illA / 100),'--k',  cie.lambda,(cie.illD50 / 100),'--r', ...
    cie.lambda,(cie.illD65 / 100),'--b');
legend('blackbody (2856K)', 'blackbody (5003K)', 'blackbody (6504K)', ...
    'illuminant A', 'illuminant D50', 'illuminant D65', 'Location','best');
title('blackbody and standard illuminant spectra');
xlabel('wavelength(nm)');
ylabel('relative power');

figure(2);
hold on;

plot(cie.lambda,cie.cmf2deg(:,1,:),'r', cie.lambda,cie.cmf2deg(:,2,:),'g', ...
    cie.lambda,cie.cmf2deg(:,3,:),'b',  cie.lambda,cie.cmf10deg(:,1,:),'--r',...
    cie.lambda,cie.cmf10deg(:,2,:),'--g',  cie.lambda,cie.cmf10deg(:,3,:),'--b');
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', 'Location','best');
title('CIE standard observer CMFs');
xlabel('wavelength(nm)');
ylabel('tristimulus values');
% do this for the rest of the data
```





step 4

create ref2XYZ in the file ref2XYZ.m

```
function XYZ = ref2XYZ(ref,cmfs,ill);
% simple version of ref2XYZ that doesn't use matrix mults
```

```
%compute normalizing constant for the illuminant
k = 100./sum(cmfs(:,2).*ill);

%compute the XYZs
X = k.*sum(cmfs(:,1).*ill.*ref);
Y = k.*sum(cmfs(:,2).*ill.*ref);
Z = k.*sum(cmfs(:,3).*ill.*ref);

% return them in a 3xn array
XYZ = [X;Y;Z];

end
```

step 5

test ref2XYZ

```
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
```

```
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 6

create XYZ2xyY in the file XYZ2xyY.m

```
function xyY = XYZ2xyY(XYZ)

    % Split the matrix into corresponding row vectors
    X = XYZ(1,:,:);
    Y = XYZ(2,:,:);
    Z = XYZ(3,:,:);

    % calculate chromaticitity coords
    x = X ./ (X + Y + Z);
    y = Y ./ (X + Y + Z);

    % reconstruct & return xyY matrix
    xyY = [x;y;Y];

end
```

step 7

test XYZ2xyY

```
CC_xyYs = XYZ2xyY(CC_XYZs)
```

```
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
```

step 8

load the spectral data for the color patches

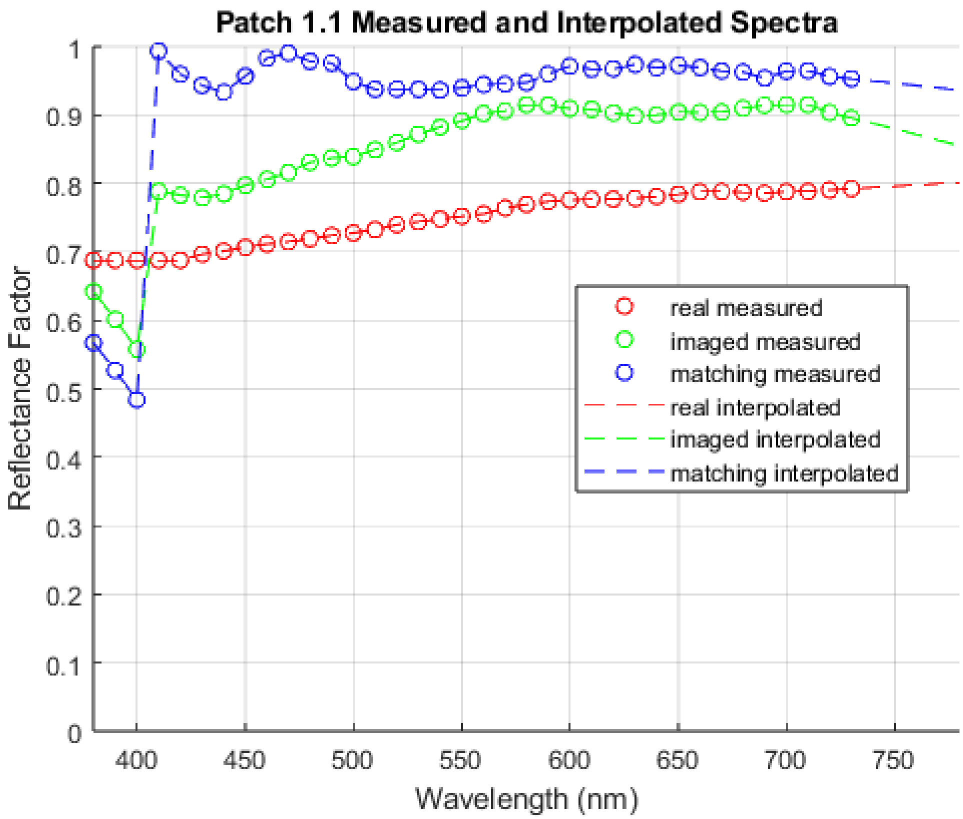
```
% define ColorMunki/Argyll/spotread measurement wavelengths
cm_lams = 380:10:730;

cm_h_offset_im = 18;
cm_h_offset_r = 19;

% load and normalize the measured spectral data for the patch #1
data = importdata('1.1_real.sp', ' ', cm_h_offset_r);
real_11 = data.data/100;
data = importdata('1.1_imaged.sp', ' ', cm_h_offset_im);
imaged_11 = data.data/100;
data = importdata('1.1_matching.sp', ' ', cm_h_offset_im);
matching_11 = data.data/100;

% repeat for patch #2
data = importdata('1.2_real.sp', ' ', cm_h_offset_r);
real_12 = data.data/100;
data = importdata('1.2_imaged.sp', ' ', cm_h_offset_im);
imaged_12 = data.data/100;
data = importdata('1.2_matching.sp', ' ', cm_h_offset_im);
matching_12 = data.data/100;
```

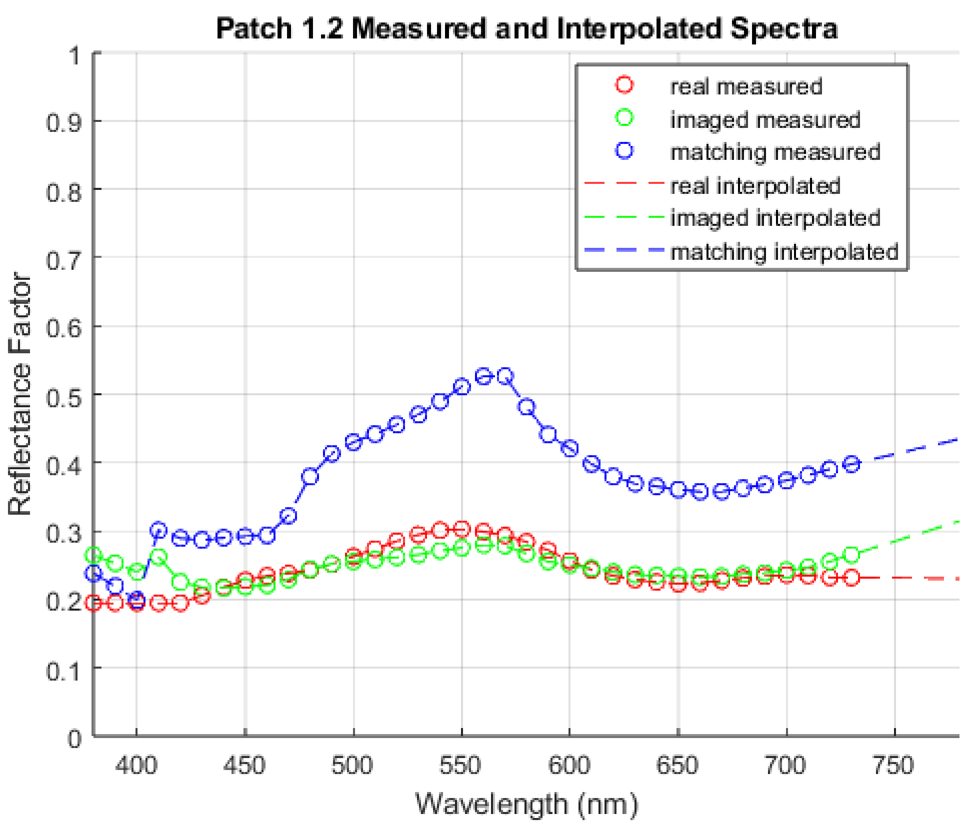
step 9

interpolate and plot the original and interpolated data

```
% interpolate/extrapolate the CM spectral data to 380-780, 5nm

% Patch #1
real_11i = interp1(cm_lams, real_11, cie.lambda, 'linear', 'extrap');
imaged_11i = interp1(cm_lams, imaged_11, cie.lambda, 'linear', 'extrap');
matching_11i = interp1(cm_lams, matching_11, cie.lambda, 'linear', 'extrap');

% Patch #2
real_12i = interp1(cm_lams, real_12, cie.lambda, 'linear', 'extrap');
imaged_12i = interp1(cm_lams, imaged_12, cie.lambda, 'linear', 'extrap');
matching_12i = interp1(cm_lams, matching_12, cie.lambda, 'linear', 'extrap');

% create a figure for patch #1 that confirms the process
figure;
hold on;

plot(cm_lams, real_11, 'ro', 'DisplayName', 'real measured');
plot(cm_lams, imaged_11, 'go', 'DisplayName', 'imaged measured');
plot(cm_lams, matching_11, 'bo', 'DisplayName', 'matching measured');

plot(cie.lambda, real_11i, 'r--', 'DisplayName', 'real interpolated');
plot(cie.lambda, imaged_11i, 'g--', 'DisplayName', 'imaged interpolated');
plot(cie.lambda, matching_11i, 'b--', 'DisplayName', 'matching interpolated');

title('Patch 1.1 Measured and Interpolated Spectra');
xlabel('Wavelength (nm)');
ylabel('Reflectance Factor');
legend('Location', 'best');;
grid on;
xlim([380 780]);
```

```
ylim([0 1]);

% Figure for patch 2
figure;
hold on;

plot(cm_lams, real_12, 'ro', 'DisplayName', 'real measured');
plot(cm_lams, imaged_12, 'go', 'DisplayName', 'imaged measured');
plot(cm_lams, matching_12, 'bo', 'DisplayName', 'matching measured');

plot(cie.lambda, real_12i, 'r--', 'DisplayName', 'real interpolated');
plot(cie.lambda, imaged_12i, 'g--', 'DisplayName', 'imaged interpolated');
plot(cie.lambda, matching_12i, 'b--', 'DisplayName', 'matching interpolated');

title('Patch 1.2 Measured and Interpolated Spectra');
xlabel('Wavelength (nm)');
ylabel('Reflectance Factor');
legend('Location', 'best');
grid on;
xlim([380 780]);
ylim([0 1]);
```





step 10

load the measured XYZ data for the patches, calculate XYZs from the interpolated spectra and print a table comparing the results

```
% load and extract the CM measured XYZs
real = importdata('1_XYZ_Labs_real.txt');
imaged = importdata('1_XYZ_Labs_imaged.txt');
matching = importdata('1_XYZ_Labs_matching.txt');

XYZmeas.real_11 = real.data(1,2:4)';
XYZmeas.imaged_11 = imaged.data(1,2:4)';
XYZmeas.matching_11 = matching.data(1,2:4)';

XYZmeas.real_12 = real.data(2,2:4)';
XYZmeas.imaged_12 = imaged.data(2,2:4)';
XYZmeas.matching_12 = matching.data(2,2:4)';

% calculate the XYZs from the spectral data
XYZcalc.real_11 = ref2XYZ(real_11i,cie.cmf2deg,cie.illD50);
XYZcalc.imaged_11 = ref2XYZ(imaged_11i,cie.cmf2deg,cie.illD50);
XYZcalc.matching_11 = ref2XYZ(matching_11i,cie.cmf2deg,cie.illD50);

XYZcalc.real_12 = ref2XYZ(real_12i,cie.cmf2deg,cie.illD50);
XYZcalc.imaged_12 = ref2XYZ(imaged_12i,cie.cmf2deg,cie.illD50);
XYZcalc.matching_12 = ref2XYZ(matching_12i,cie.cmf2deg,cie.illD50);


% print formatted tables of measured and calculated XYZs for the color patches
fprintf('Measured and calculated tristimulus values\n\n');
fprintf('\t\t\t patch 1.1\n');
fprintf('\t\tmeasured\t\tcalculated\n');
fprintf('\t      X\t\tY\tZ\tX\tY\t  Z\n');
fprintf('%8s% 9.4f% 9.4f% 9.4f% 9.4f% 9.4f% 9.4f\n', 'real', ...
    XYZmeas.real_11', XYZcalc.real_11');
fprintf('%8s% 9.4f% 9.4f% 9.4f% 9.4f% 9.4f% 9.4f\n', 'imaged', ...
    XYZmeas.imaged_11', XYZcalc.imaged_11');
fprintf('%8s% 9.4f% 9.4f% 9.4f% 9.4f% 9.4f% 9.4f\n', 'matching', ...
    XYZmeas.matching_11', XYZcalc.matching_11');

fprintf('\n\n');
fprintf('\t\t\t patch 1.2\n');
fprintf('\t\tmeasured\t\tcalculated\n');
fprintf('\t      X\t\tY\tZ\tX\tY\t  Z\n');
fprintf('%8s% 9.4f% 9.4f% 9.4f% 9.4f% 9.4f% 9.4f\n', 'real', ...
    XYZmeas.real_12', XYZcalc.real_12');
fprintf('%8s% 9.4f% 9.4f% 9.4f% 9.4f% 9.4f% 9.4f\n', 'imaged', ...
    XYZmeas.imaged_12', XYZcalc.imaged_12');
fprintf('%8s% 9.4f% 9.4f% 9.4f% 9.4f% 9.4f% 9.4f\n', 'matching', ...
    XYZmeas.matching_12', XYZcalc.matching_12');
```

```
Measured and calculated tristimulus values

                         patch 1.1
                measured                calculated
              X         Y        Z        X        Y          Z
    real  73.4334  75.6109  58.5145  73.4272  75.6094  58.5257
  imaged  85.7940  88.8586  66.3455  85.7827  88.8525  66.3528
matching  92.4689  95.0103  79.3535  92.4571  95.0145  79.3425
```

```
                     patch 1.2
              measured                  calculated
             X          Y        Z        X        Y          Z
    real  24.7947  27.7476  18.9882  24.7922  27.7377  18.9920
  imaged  24.1535  26.1929  18.7744  24.1542  26.1875  18.7918
matching  40.3188  46.0387  26.3228  40.3173  46.0177  26.3524
```

step 11

calculate measured and calculated xyYs and print a table comparing the results

```
% calculate the xyYs from the CM measured XYZs
xyYmeas.real_11 = XYZ2xyY(XYZmeas.real_11);
xyYmeas.imaged_11 = XYZ2xyY(XYZmeas.imaged_11);
xyYmeas.matching_11 = XYZ2xyY(XYZmeas.matching_11);

xyYmeas.real_12 = XYZ2xyY(XYZmeas.real_12);
xyYmeas.imaged_12 = XYZ2xyY(XYZmeas.imaged_12);
xyYmeas.matching_12 = XYZ2xyY(XYZmeas.matching_12);

xyYcalc.real_11 = XYZ2xyY(XYZcalc.real_11);
xyYcalc.imaged_11 = XYZ2xyY(XYZcalc.imaged_11);
xyYcalc.matching_11 = XYZ2xyY(XYZcalc.matching_11);

xyYcalc.real_12 = XYZ2xyY(XYZcalc.real_12);
xyYcalc.imaged_12 = XYZ2xyY(XYZcalc.imaged_12);
xyYcalc.matching_12 = XYZ2xyY(XYZcalc.matching_12);


% print formatted tables of measured and calculated xyYs for the color patches
fprintf('\n\nMeasured and calculated chromaticity coordinates\n\n');
fprintf('\t\t\t patch 1.1\n');
fprintf('\t\tmeasured\t\tcalculated\n');
fprintf('\t      x\t\ty\tY\tx\ty\t  Y\n');
fprintf('%8s% 9.4f% 9.4f% 9.4f% 9.4f% 9.4f% 9.4f\n', 'real', ...
    xyYmeas.real_11', xyYcalc.real_11');
fprintf('%8s% 9.4f% 9.4f% 9.4f% 9.4f% 9.4f% 9.4f\n', 'imaged', ...
    xyYmeas.imaged_11', xyYcalc.imaged_11');
fprintf('%8s% 9.4f% 9.4f% 9.4f% 9.4f% 9.4f% 9.4f\n', 'matching', ...
    xyYmeas.matching_11', xyYcalc.matching_11');

fprintf('\n\n');
fprintf('\t\t\t patch 1.2\n');
fprintf('\t\tmeasured\t\tcalculated\n');
fprintf('\t      x\t\ty\tY\tx\ty\t  Y\n');
fprintf('%8s% 9.4f% 9.4f% 9.4f% 9.4f% 9.4f% 9.4f\n', 'real', ...
    xyYmeas.real_12', xyYcalc.real_12');
fprintf('%8s% 9.4f% 9.4f% 9.4f% 9.4f% 9.4f% 9.4f\n', 'imaged', ...
    xyYmeas.imaged_12', xyYcalc.imaged_12');
fprintf('%8s% 9.4f% 9.4f% 9.4f% 9.4f% 9.4f% 9.4f\n', 'matching', ...
    xyYmeas.matching_12', xyYcalc.matching_12');
```

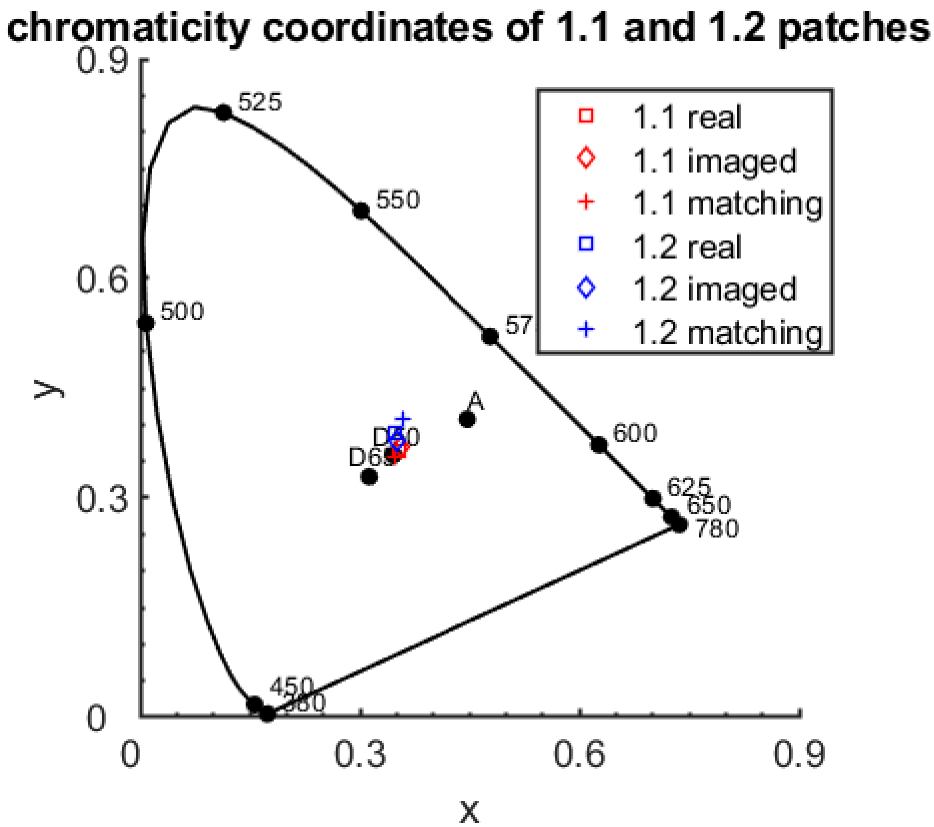
```
Measured and calculated chromaticity coordinates
```

```
                       patch 1.1
              measured                 calculated
             x         y        Y         x        y         Y
      real   0.3538    0.3643   75.6109   0.3538   0.3643   75.6094
    imaged   0.3560    0.3687   88.8586   0.3560   0.3687   88.8525
  matching   0.3465    0.3561   95.0103   0.3465   0.3561   95.0145


                       patch 1.2
              measured                 calculated
             x         y        Y         x        y         Y
      real   0.3466    0.3879   27.7476   0.3466   0.3878   27.7377
    imaged   0.3494    0.3789   26.1929   0.3494   0.3788   26.1875
  matching   0.3578    0.4086   46.0387   0.3578   0.4084   46.0177
```

step 12

plot the calculated chromaticity coordinates for the patches on a chromaticity diagram

```
% plot the chromaticity diagram skeleton
plot_chrom_diag_skel;

line_weight = 1.0;


% plot the data for 1.1
x = xyYcalc.real_11(1);
y = xyYcalc.real_11(2);
h(1) = plot(x,y,'rs','LineWidth', line_weight);

x = xyYcalc.imaged_11(1);
y = xyYcalc.imaged_11(2);
h(2) = plot(x,y,'rd','LineWidth', line_weight);

x = xyYcalc.matching_11(1);
y = xyYcalc.matching_11(2);
h(3) = plot(x,y,'r+','LineWidth', line_weight);


% plot the data for 1.2
x = xyYcalc.real_12(1);
y = xyYcalc.real_12(2);
h(4) = plot(x,y,'bs','LineWidth', line_weight);

x = xyYcalc.imaged_12(1);
y = xyYcalc.imaged_12(2);
h(5) = plot(x,y,'bd','LineWidth', line_weight);

x = xyYcalc.matching_12(1);
y = xyYcalc.matching_12(2);
h(6) = plot(x,y,'b+','LineWidth', line_weight);

legend(h, '1.1 real','1.1 imaged', '1.1 matching',...
    '1.2 real','1.2 imaged', '1.2 matching','Location','best');
title('chromaticity coordinates of 1.1 and 1.2 patches');
```



feedback

i. Who did which parts

Shakira - parts 2, 3, 6, 7, 10

Hridiza - parts 4, 5, 8, 9, 11, 12, 13

ii. Problems

- The chromaticity plot has values that are very close together, which is making them hard to discern

- Formatting the tables was challenging

iii. Valuable parts

- Learning how to interpret and use the measured data to gain insights

iv. Improvements

- A section asking us to interpret the chromaticity coordinates might be beneficial

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