Table of Contents

```
function LinearizationTutorial

%
% 11/17/2014  npc  Wrote it.
%
```

Initialize state

```
    close all;
    global figNum
    figNum = 0;
```

Load a calibration file (generated by running OOC_calibrateMonitor)

Specify the calibration file to load

```
    calFileName = 'ViewSonicProbe';
    % Specify to get the most recent entry
    calStruct= LoadCalFile(calFileName);
```

Instantiate a @CalStruct object that will handle controlled access to the calibration data.

```
    [calStructOBJ, ~] = ObjectToHandleCalOrCalStruct(calStruct);
    % Clear the imported calStruct. From now on, all access to cal data is via the
    clear 'calStruct';
```

Print some calibration information

```
    DescribeMonCal(calStructOBJ);
```

```
Calibration:
  * Computer: nicolas's Manta, 10.9.4
  * Screen: 2
  * Monitor: NicolasViewSonic
  * Video driver: object-oriented calibration
  * Dac size: 8
  * Frame rate: 60 hz
  * Calibration performed by npc
  * Calibration performed on 07-Aug-2014  1:37:29 PM
  * Calibration program: OOC_calibrateMonitor
  * Comment: Office ViewSonic
  * Calibrated device has 3 primaries
  * Gamma fit type crtPolyLinear
```

Retrieve the wavelength sampling that was used to take the measurement

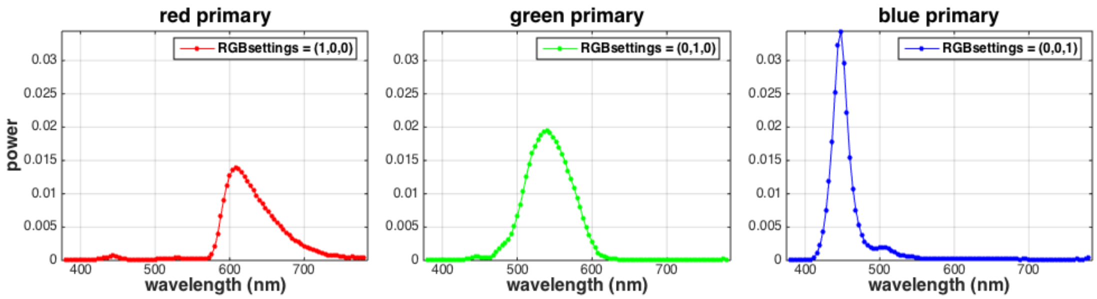
```
S = calStructOBJ.get('S');
```

Retrieve the measured spectra of the display's primaries.

```
P_device = calStructOBJ.get('P_device');
```

Plot the spectra

```
PlotPrimarySpectra(S, P_device);
```

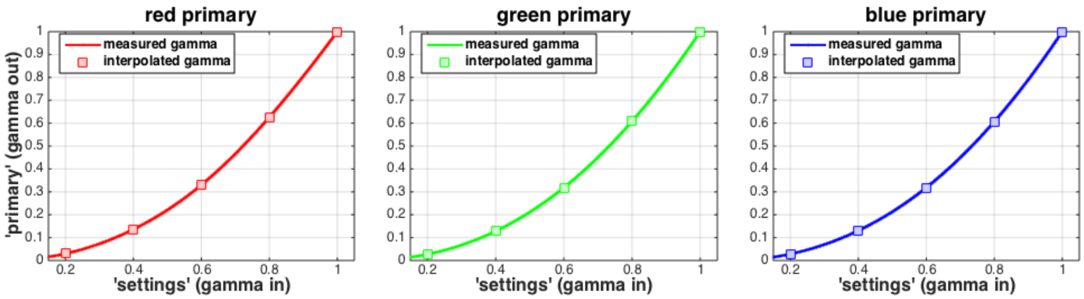


Retrieve the gamma tables (raw and interpolated)

```
rawGammaInput = calStructOBJ.get('rawGammaInput');
rawGammaTable = calStructOBJ.get('rawGammaTable');
gammaInput    = calStructOBJ.get('gammaInput');
gammaTable    = calStructOBJ.get('gammaTable');
```

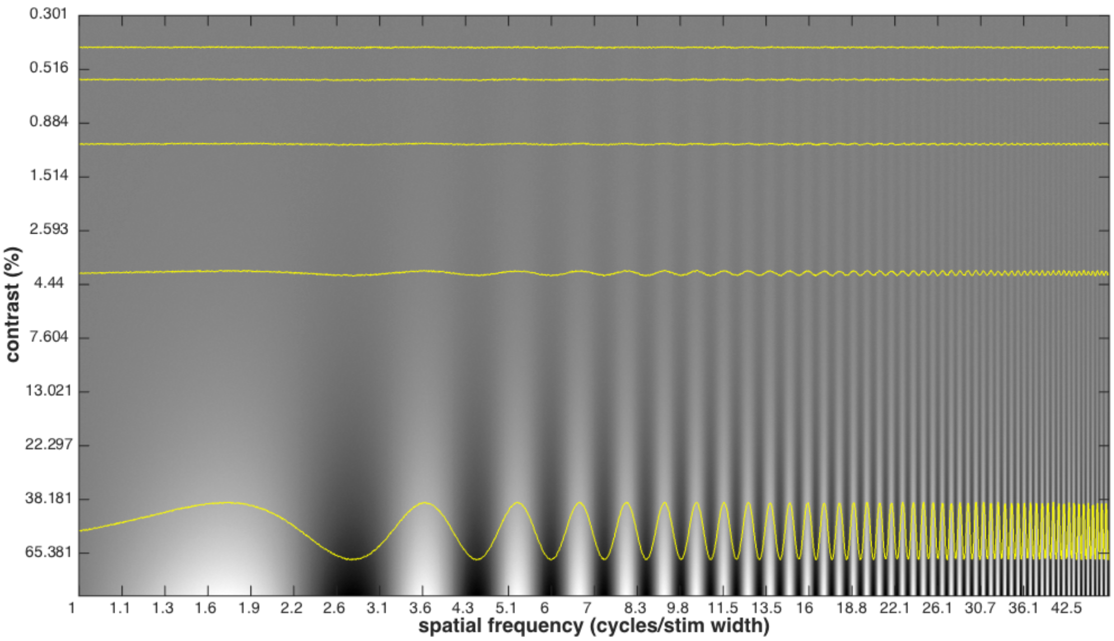
Plot the gamma tables

```
PlotGammaTables(rawGammaInput, rawGammaTable, gammaInput, gammaTable);
```



Load desired stimulus. This is specified in primary values, i.e. gamma out values

```
desiredStimInPrimaryValues = MakeContrastSensitivityStimulus;
```



Compute stimulus to be delivered to the frame buffer. This is in settings values, i.e. gamma in

1. Select a gamma inversion method option. Choose from:

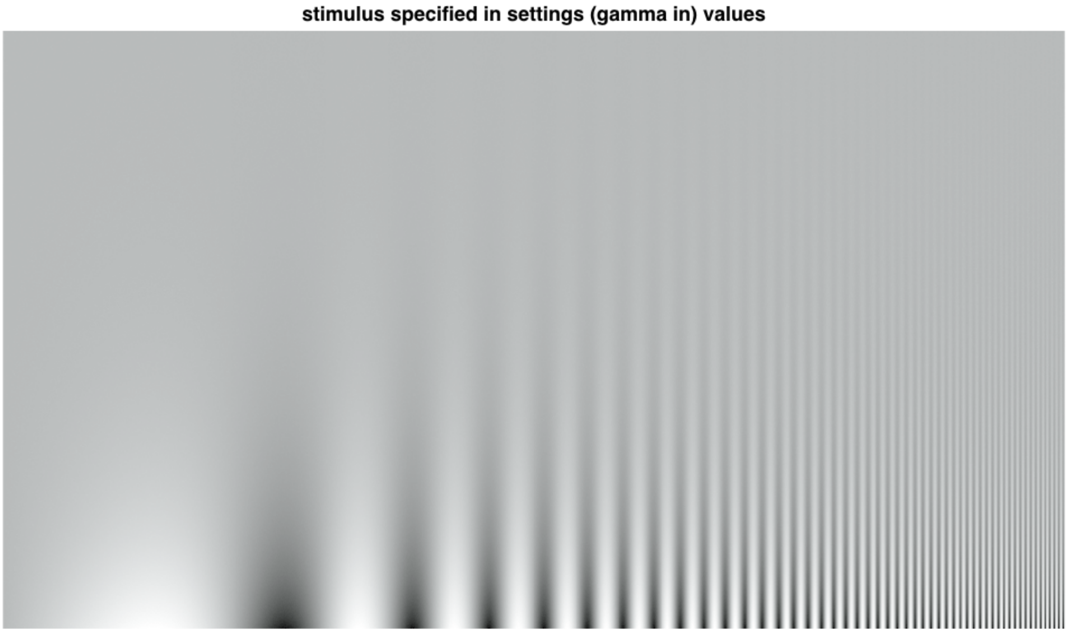
- gammaMode = 0 - search table using linear interpolation via interp1.
- gammaMode = 1 - inverse table lookup. Fast but less accurate.

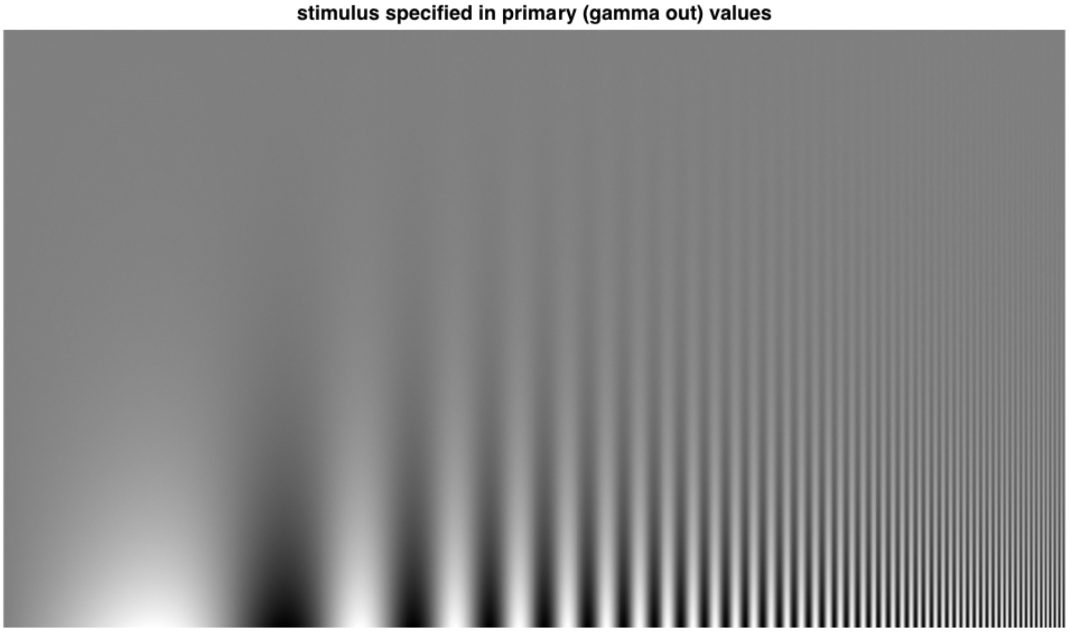
- gammaMode = 2 - exhaustive search
- If gammaMode == 1, then you may specify the precision of the inverse table. The default is 1000 levels.

```
gammaInversionMethod = 0;
SetGammaMethod(calStructOBJ, gammaInversionMethod);

% 2. Reshape stimInPrimaries matrix (MxNx3) into a [3 x (MxN)] matrix for effi
[calFormatStimInPrimaryValues,nX,nY] = ImageToCalFormat(desiredStimInPrimaryVa

% 3. Compute stimulus in settings.
calFormatStimInSettingsValues = PrimaryToSettings(calStructOBJ, calFormatStimI

% Reshape back to image coordinates, i.e., MxNx3. This is the stimulus that
% should be delivered to the frame buffer for display.
stimInSettingsValues = CalFormatToImage(calFormatStimInSettingsValues,nX,nY);
```

Plot the gamma-in and gamma-out versions of the stimulus

```
PlotStimuli(stimInSettingsValues, desiredStimInPrimaryValues);
```

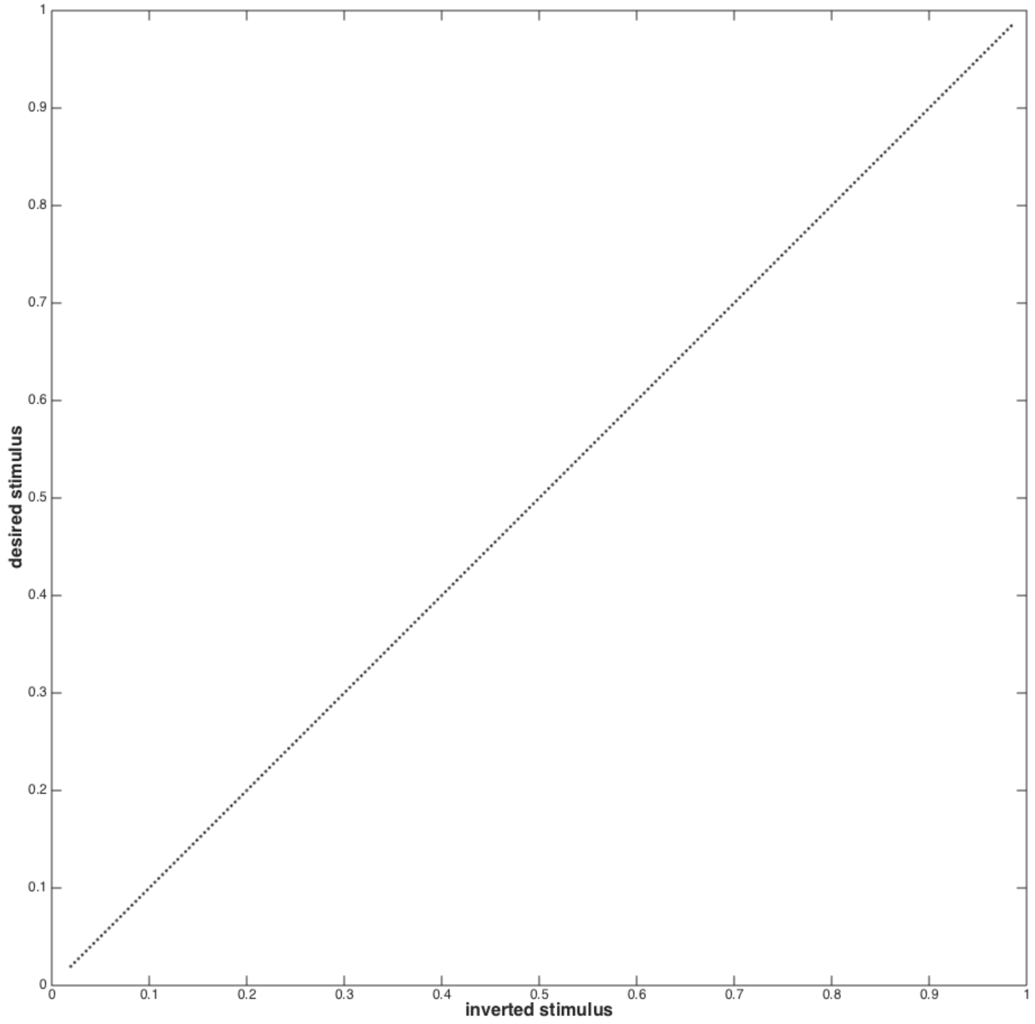




Check that the stimulus is indeed linearized

Invert the stimulus in settings values to get the stimulus in primary values

```
calFormatInvertedStimInPrimaryValues = SettingsToPrimary(calStructOBJ,calForma
invertedStimInPrimaryValues = CalFormatToImage(calFormatInvertedStimInPrimaryV

% Plot the desired vs the inverted stimulus
PlotCorrespondence(invertedStimInPrimaryValues(:), desiredStimInPrimaryValues(
```



```
end


function PlotCorrespondence(invertedStim, desiredStim)
    global figNum
    figNum = figNum + 1;

    % Steup subplot position vectors
    subplotPosVectors = NicePlot.getSubPlotPosVectors(...
        'rowsNum',      1, ...
        'colsNum',      1, ...
        'heightMargin', 0.01, ...
        'widthMargin',  0.01, ...
        'leftMargin',   0.1, ...
        'bottomMargin', 0.1, ...
        'topMargin',    0.02);
    hFig = figure(figNum);
    set(hFig, 'Position', [100 100 1000 1000]);

    minVal = min([min(invertedStim) min(desiredStim)]);
    maxVal = max([max(invertedStim) max(desiredStim)]);

    subplot('Position', subplotPosVectors(1,1).v);
    plot(invertedStim(1:10:end), desiredStim(1:10:end), 'k.');
    hold on;
    axis 'square'
    xlabel('inverted stimulus');
    ylabel('desired stimulus');
     % Set fonts for all axes, legends, and titles
    NicePlot.setFontSizes(hFig, 'FontSize', 12);

end


function PlotStimuli(stimInSettings, stimInPrimaries)
    global figNum
    figNum = figNum + 1;

    % Steup subplot position vectors
    subplotPosVectors = NicePlot.getSubPlotPosVectors(...
        'rowsNum',      2, ...
        'colsNum',      1, ...
        'heightMargin', 0.07, ...
        'widthMargin',  0.01, ...
        'leftMargin',   0.02, ...
        'bottomMargin', 0.02, ...
        'topMargin',    0.02);

    hFig = figure(figNum);
    set(hFig, 'Position', [100 100 1000 1210]);

    % generate subplot with stim in settings
    subplot('Position', subplotPosVectors(1,1).v);
    imshow(stimInSettings);
    title('stimulus specified in settings (gamma in) values');

    % generate subplot with stim in primaries
    subplot('Position', subplotPosVectors(2,1).v);
    imshow(stimInPrimaries)
    title('stimulus specified in primary (gamma out) values');

    % Set fonts for all axes, legends, and titles
    NicePlot.setFontSizes(hFig, 'FontSize', 12);
end



function PlotGammaTables(rawGammaInput, rawGammaTable, gammaInput, gammaTable)
    global figNum
    figNum = figNum + 1;
```

```
% Steup subplot position vectors
subplotPosVectors = NicePlot.getSubPlotPosVectors(...
    'rowsNum',      1, ...
    'colsNum',      size(rawGammaTable,2), ...
    'widthMargin',  0.05, ...
    'leftMargin',   0.07, ...
    'bottomMargin', 0.15, ...
    'topMargin',    0.1);

% Specify line colors, here for 3 primaries
lineColors = [...
    1.0 0.0 0.0;
    0.0 1.0 0.0;
    0.0 0.0 1.0 ];

markerFaceColors = [...
    1.0 0.8 0.8;
    0.8 1.0 0.8;
    0.8 0.8 1.0 ];

% Specify titles
titles = {'red primary', 'green primary', 'blue primary'};

% Specify no legends
legends = {'measured gamma', 'interpolated gamma'};

hFig = figure(figNum);
set(hFig, 'Position', [100 100 1000 275]);

for primaryIndex = 1:size(rawGammaTable,2)
    % generate subplot
    subplot('Position', subplotPosVectors(1,primaryIndex).v);

    % raw data: squares, interpolated data (1024 values): lines
    plot(gammaInput, gammaTable(:,primaryIndex), ...
        '.-', 'Color', lineColors(primaryIndex,:), 'LineWidth', 2.0);
    hold on;
    plot(rawGammaInput, rawGammaTable(:,primaryIndex), ...
        'ks',  'MarkerSize', 10, ...
        'MarkerEdgeColor', lineColors(primaryIndex,:), 'MarkerFaceColor', mark
    hold off;

    % add legends
    legend(legends, 'Location','NorthWest');

    box on; grid on;

    % set plot limits
    set(gca, 'XLim', [rawGammaInput(1)-0.05 rawGammaInput(end)+0.05], 'YLim',

    % set plot labels
    xlabel('''settings'' (gamma in)');  title(titles{primaryIndex});
    if (primaryIndex == 1)
```

```
            ylabel('''primary'' (gamma out)');
        end
    end

    % Set fonts for all axes, legends, and titles
    NicePlot.setFontSizes(hFig, 'FontSize', 12);
end


function PlotPrimarySpectra(S, P_device)
    global figNum
    figNum = figNum + 1;

    wavelengthAxis = SToWls(S);

    % Steup subplot position vectors
    subplotPosVectors = NicePlot.getSubPlotPosVectors(...
        'rowsNum',      1, ...
        'colsNum',      size(P_device,2), ...
        'widthMargin',  0.05, ...
        'leftMargin',   0.07, ...
        'bottomMargin', 0.15, ...
        'topMargin',    0.1);

    % Specify line colors, here for 3 primaries
    lineColors = [...
        1.0 0.0 0.0;
        0.0 1.0 0.0;
        0.0 0.0 1.0 ];

    % Specify titles
    titles = {'red primary', 'green primary', 'blue primary'};

    % Specify legends
    legends = {'RGBsettings = (1,0,0)', 'RGBsettings = (0,1,0)', 'RGBsettings = (0

    hFig = figure(figNum);
    set(hFig, 'Position', [100 100 1000 275]);

    for primaryIndex = 1:size(P_device,2)

        % generate subplot
        subplot('Position', subplotPosVectors(1,primaryIndex).v);
        plot(wavelengthAxis, P_device(:,primaryIndex), ...
            '.-', 'Color', lineColors(primaryIndex,:), 'MarkerSize', 16);
        box on; grid on;

        % set plot limits
        set(gca, 'XLim', [wavelengthAxis(1)-5 wavelengthAxis(end)+5], 'YLim', [0 m

        % set plot labels
        xlabel('wavelength (nm)');  title(titles{primaryIndex});
        if (primaryIndex == 1)
            ylabel('power');
        end

        % set legend
        legend(legends{primaryIndex}, 'Location','NorthEast');
    end

    % Set fonts for all axes, legends, and titles
    NicePlot.setFontSizes(hFig, 'FontSize', 12);
end


function CSF = MakeContrastSensitivityStimulus

    rowsNum = 1080;
    colsNum = 1920;
    CSF = zeros(rowsNum, colsNum);

    lowestSF =  1.0;
    highestSF = 50.0;
    lowestContrast = 0.003;
    highestContrast = 1.0;

    stepSF = (highestSF/lowestSF)^(1.0/colsNum);
    stepContrast = (highestContrast/lowestContrast)^(1.0/rowsNum);

    contrast = lowestContrast;
    contrastAxis = zeros(rowsNum,1);
    sfAxis = zeros(colsNum,1);

    for row = 1:rowsNum
        contrast = contrast * stepContrast;
        contrastInUse = contrast;
        if (contrastInUse  < lowestContrast)
            contrastInUse = 0.0;
        end
        contrastAxis(row) = floor(contrastInUse*100*1000)/1000;
        currentSF = lowestSF/colsNum;
        for col = 1:colsNum
            currentSF = currentSF * stepSF;
            sfAxis(col) = floor(currentSF*colsNum*10)/10;
            CSF(row,col) = contrastInUse * sin(2.0*pi*col*currentSF);
        end % col
    end % row

    % add some noise to reduce contrast quantization effects (no noise when levels
    levels = 6;
    CSF = CSF + 1/255.0*(mod(round(rand(rowsNum,colsNum)*levels),levels)-(levels/2

    % normalize to [0..1]
    CSF(CSF < -1) = -1;
    CSF(CSF > 1) = 1;
    CSF = 0.5*(1+CSF);

    displayCSF = true;
```

```
displayNormalizedSlices = false;
displayType = 'Analog';
displayType = '8bit';
%displayType = '10bit';

if (displayCSF)

    global figNum
    figNum = figNum + 1;

    % Steup subplot position vectors
    subplotPosVectors = NicePlot.getSubPlotPosVectors(...
        'rowsNum',      1, ...
        'colsNum',      1, ...
        'heightMargin', 0.01, ...
        'widthMargin',  0.01, ...
        'leftMargin',   0.07, ...
        'bottomMargin', 0.07, ...
        'topMargin',    0.01);

    hFig = figure(figNum);
    set(hFig, 'Position', [100 100 1000 575]);

    if (strcmp(displayType, '8bit'))
        CSF = floor(256*CSF+0.5)/255;
    elseif (strcmp(displayType, '10bit'))
        CSF = floor(1024*CSF+0.5)/1024;
    end

    subplot('Position', subplotPosVectors(1,1).v);
    imagesc(1:colsNum, 1:rowsNum, CSF);
    hold on;
    if (displayNormalizedSlices)
        gain = 30;
    else
        gain = 200;
    end
    for row = [60 120 240 480 960]
        slice = -(CSF(row,1:colsNum)-0.5);
        if (displayNormalizedSlices)
            slice = slice/max(abs(slice(:)));
        end
        stairs(1:colsNum, slice*gain+row, 'y-');
    end
    hold off
    labeledRows = [1:100:rowsNum];
    labeledCols = [1:80:colsNum];
    set(gca, 'CLim', [0 1], 'XLim', [1 colsNum], 'YLim', [1 rowsNum], ...
        'XTick', labeledCols,  'XTickLabel', sfAxis(labeledCols), 'YTick',  la
    ylabel('contrast (%)');
    xlabel('spatial frequency (cycles/stim width)');
    axis 'image'
    colormap(gray(1024));
```

```
        % Set fonts for all axes, legends, and titles
        NicePlot.setFontSizes(hFig, 'FontSize', 14);
    end

    % Make it a NxMx3 RGB matrix
    CSF = repmat(CSF, [1 1 3]);
end
```

Published with MATLAB® R2014b