Instruction

Calibration Example:

1. Collected data, Folder structure:
The extracted colors of images (sRGB and Raw images) and other necessary files, they are in the same folder.

2. Start the Interface in Matlab
2.1 Tested system:
   - Windows XP 32bit, 4GB of RAM
   - Matlab 7.10.0 (R2010a)

   Note: the code contains C++ files, if your system is different from the tested one, please recompile those files. For more information about compiling C++ files in matlab, please refer to http://www.mathworks.com/support/tech-notes/1600/1605.html#C_compiling.

2.2 Run the Interface
radiometricCal.fig
If everything is OK, you will see the interface:

Click run
2.3 Brief introduction about the interface

3. Initialize for the data set as an example. If it is the first time of initializing for this data set, it will take some time to construct necessary files. Please wait for a while after even you think the waiting bar has disappeared.
4. Load image pair BTF (brightness transfer function) data
For this example, I loaded those files: (Those files are automatically generated from text files of extracted colors during the previous initialize step.)

```
btf_Canon EOS-1Ds Mark III_ISO200_L0_F8_R1.25_T0.100000-0.125000.txt
btf_Canon EOS-1Ds Mark III_ISO200_L0_F8_R1.25_T0.200000-0.250000.txt
btf_Canon EOS-1Ds Mark III_ISO200_L0_F8_R1.25_T0.400000-0.500000.txt
btf_Canon EOS-1Ds Mark III_ISO200_L0_F8_R1.54_T0.050000-0.076923.txt
btf_Canon EOS-1Ds Mark III_ISO200_L0_F8_R1.60_T0.025000-0.040000.txt
btf_Canon EOS-1Ds Mark III_ISO200_L0_F8_R1.60_T0.125000-0.200000.txt
btf_Canon EOS-1Ds Mark III_ISO200_L1_F8_R1.25_T0.100000-0.125000.txt
btf_Canon EOS-1Ds Mark III_ISO200_L1_F8_R1.25_T0.200000-0.250000.txt
btf_Canon EOS-1Ds Mark III_ISO200_L1_F8_R1.54_T0.050000-0.076923.txt
btf_Canon EOS-1Ds Mark III_ISO200_L1_F8_R1.60_T0.025000-0.040000.txt
btf_Canon EOS-1Ds Mark III_ISO200_L1_F8_R1.60_T0.125000-0.200000.txt
btf_Canon EOS-1Ds Mark III_ISO200_L1_F8_R1.60_T0.250000-0.400000.txt
btf_Canon EOS-1Ds Mark III_ISO200_L2_F8_R1.25_T0.040000-0.050000.txt
btf_Canon EOS-1Ds Mark III_ISO200_L2_F8_R1.25_T0.100000-0.125000.txt
btf_Canon EOS-1Ds Mark III_ISO200_L2_F8_R1.54_T0.050000-0.076923.txt
btf_Canon EOS-1Ds Mark III_ISO200_L2_F8_R1.60_T0.025000-0.040000.txt
btf_Canon EOS-1Ds Mark III_ISO200_L2_F8_R1.60_T0.125000-0.200000.txt
btf_Canon EOS-1Ds Mark III_ISO200_L2_F8_R1.60_T0.250000-0.400000.txt
btf_Canon EOS-1Ds Mark III_ISO200_L2_F8_R1.60_T0.400000-0.050000.txt
btf_Canon EOS-1Ds Mark III_ISO200_L2_F8_R1.25_T0.100000-0.125000.txt
btf_Canon EOS-1Ds Mark III_ISO200_L2_F8_R1.25_T0.040000-0.050000.txt
btf_Canon EOS-1Ds Mark III_ISO200_L2_F8_R1.54_T0.050000-0.076923.txt
btf_Canon EOS-1Ds Mark III_ISO200_L2_F8_R1.60_T0.025000-0.040000.txt
```
btf_Canon EOS-1Ds Mark III_ISO200_L2_F8_R1.60_T0.025000-0.040000.txt
btf_Canon EOS-1Ds Mark III_ISO200_L2_F8_R1.60_T0.125000-0.200000.txt
btf_Canon EOS-1Ds Mark III_ISO200_L2_F8_R1.60_T0.250000-0.400000.txt
btf_Canon EOS-1Ds Mark III_ISO200_L3_F8_R1.25_T0.040000-0.050000.txt
btf_Canon EOS-1Ds Mark III_ISO200_L3_F8_R1.25_T0.100000-0.125000.txt
btf_Canon EOS-1Ds Mark III_ISO200_L3_F8_R1.25_T0.200000-0.250000.txt
btf_Canon EOS-1Ds Mark III_ISO200_L3_F8_R1.54_T0.050000-0.076923.txt
btf_Canon EOS-1Ds Mark III_ISO200_L3_F8_R1.60_T0.025000-0.040000.txt
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btf_Canon EOS-1Ds Mark III_ISO200_L3_F8_R1.60_T0.250000-0.400000.txt
btf_Canon EOS-1Ds Mark III_ISO200_L4_F8_R1.25_T0.025000-0.040000.txt
btf_Canon EOS-1Ds Mark III_ISO200_L4_F8_R1.25_T0.100000-0.125000.txt
btf_Canon EOS-1Ds Mark III_ISO200_L4_F8_R1.25_T0.200000-0.250000.txt
btf_Canon EOS-1Ds Mark III_ISO200_L4_F8_R1.54_T0.050000-0.076923.txt
btf_Canon EOS-1Ds Mark III_ISO200_L4_F8_R1.54_T0.100000-0.125000.txt
btf_Canon EOS-1Ds Mark III_ISO200_L4_F8_R1.54_T0.200000-0.250000.txt
btf_Canon EOS-1Ds Mark III_ISO200_L5_F8_R1.25_T0.040000-0.050000.txt
btf_Canon EOS-1Ds Mark III_ISO200_L5_F8_R1.25_T0.100000-0.125000.txt
btf_Canon EOS-1Ds Mark III_ISO200_L5_F8_R1.25_T0.200000-0.250000.txt
btf_Canon EOS-1Ds Mark III_ISO200_L8_F8_R1.25_T0.040000-0.050000.txt
btf_Canon EOS-1Ds Mark III_ISO200_L8_F8_R1.25_T0.100000-0.125000.txt
btf_Canon EOS-1Ds Mark III_ISO200_L8_F8_R1.25_T0.200000-0.250000.txt
btf_Canon EOS-1Ds Mark III_ISO200_L8_F8_R1.54_T0.050000-0.076923.txt
btf_Canon EOS-1Ds Mark III_ISO200_L8_F8_R1.54_T0.100000-0.125000.txt
btf_Canon EOS-1Ds Mark III_ISO200_L8_F8_R1.54_T0.200000-0.250000.txt
btf_Canon EOS-1Ds Mark III_ISO200_L8_F8_R1.60_T0.025000-0.040000.txt
btf_Canon EOS-1Ds Mark III_ISO200_L8_F8_R1.60_T0.125000-0.200000.txt
btf_Canon EOS-1Ds Mark III_ISO200_L8_F8_R1.60_T0.250000-0.400000.txt
Then you will see the following figure:

Now we can start our computation.

5. Filter out the outliers for computing response functions (R, G, B channels)
5.1 Check the **valid range of the color points** to be used in response function computation.
5.2 Note that the current **outlier group** is set to be “To1”, the outliers will be recorded in outlier group “To1”. You can have more outlier groups by set current outlier group to other option and do another filtering. If you checked the outlier group, those points recorded in this group will be considered as outliers in the following computation.

![Current outlier group](image1.png)

5.3 Filtering using saturation level:

![Filtering interface](image2.png)

Usually use same **saturation level** for RGB channels; this keeps the outliers of RGB channels the same. You can have different outliers for different channel if you use different saturation levels. Here for Canon Camera, I used a quite low saturation level 0.3. For other cameras, you may use some higher values. It depends on how well the outliers are removed.

If “Patch” is checked, will remove even more color points as outliers. Usually is not recommended. “Append” means append the outliers to the current outlier group. If not checked, the record of this outlier group will be replaced with the result of this filtering.

You need to check “Apply to all” to do this filtering to all selected BTF data you loaded.

Press button “Do Filter”.

You can check the filtering result:

(Make sure you want to hide outliers in the plotting: ![Hide outliers](image3.png))
5.4 Select several appropriate BTFs to compute the response function
You may still notice that many outliers remain especially in R or B channel:
However, we are not using all BTFs to compute the response function. We have to select several appropriate BTFs, which covers the most of range [0, 255] and are also roughly evenly distributed. Here is what I selected (7 BTFs):
5.5 Refine the outlier filtering for the selected BTFs
From the above plotting, we can still see some outliers. There are two ways to remove them:
5.5.1 Manually add them to the current outlier group

Short cuts for:
- Select Current BTF ---- Keys 1, 2, …, 7
- Select Current Channel ---- Key ‘r’ or ‘g’ or ‘b’
- Add Outlier ---- Key ‘a’
- Delete Outlier ---- Key ‘d’

The outliers of the current BTF and Channel will be shown in the Index Axes:

Reset the patch ID to none, please right click on the Patch number.
5.5.2 Tune the distance to the BTF curves to filter outliers
If the outliers are not too many, just compute the response functions first.
(Please check the following steps on how to compute response function.)
When the response functions are computed, we will have the BTF curves for each BTF loaded:

We can see that the BTF curves of blue channel are not very good because outliers still exist in this channel. Usually, Green channel is much cleaner than other
channels; the BTF curves for these 3 channels are similar. So we can use the BTF curves of Green channel to further filter out the outliers left.

Check “Use G resp. only”:

Set appropriate distance threshold to filter out outliers far away from its BTF curve:

Now we get much clean samples:
5.6 Compute the response functions
5.6.1 Estimate raw related parameters

Max Raw: usually we do not have to change this. The estimation done in loading BTFs is already quite good. Be careful when these estimated Max Raw-s are different between different data sets of same camera model.

Press button “shift” to estimate the transition of raw space. Usually I will replace the estimations using numbers which are the powers of two. Button “0” is for
reseting the transition to 0. The **raw values will be normalized** using Max Raw and these numbers.

Check the “f” check box to **fix these numbers**. Otherwise when computing the response function, the algorithm will estimate the transition again instead of using this refined transition numbers.

5.6.2 Set number of basis and weights for the sample points

![Parameter Calculation](image)

**Number of Basis**: from 1 to 15 basis can be used.

**Weight**: the higher the more the color points around the center of range \([0, 255]\) will be weighted during the computation.

5.6.3 Keep the “fixed” number as negative number first

Keep this number as negative number first since we do not know what the best number is to use at this point. We will set it later.

If this number is positive \((\text{Num}_{\text{fixed}}>0)\), another constraint will be added into the computation of response function. The constraint is

\[
 f_c^{-1}(128) = \text{Num}_{\text{fixed}}, \ c \ in \ \{R, G, B\}.
\]
5.6.4 Compute the response functions and check the results

From the Matlab command window, we can find some recommendations for setting the “fixed” numbers.

Here, I set the “fixed” number to 0.110, same as the optimal one of Green channel.
Press “compute” again, we get the final response functions, please check the “Resp. Show” to plot the response functions or the fitted BTF curves:
You can save the computed response functions by pressing button “save model”. Or save the current working states by pressing button “Save Work”. Those saved data can be loaded at next run.

6. Compute the space transformation between Raw Space and sRGB space
6.1 White Balance (WB) Scales
If the camera writes the WB Scales into EXIF data of its images, we can directly use these numbers. For example, in the following figure, we save the scales of WB Li in text file “WBscales_Li.txt”, put it in the same folder of the data set.

![Image showing WB scales](image)

If we have these WBscales_Li.txt files and want to use them, do not check the “Calc WB”. Otherwise, please do check “Calc WB” if you want the algorithm to fit optimal scales for each WB.

![Parameters Calculation](image)

Ambiguity exists in the optimal WB scales fitting. We cannot recover exact numbers same as those recorded in the EXIF data (if available). The way we do it is to fix WB scales of one WB to [1 1 1] and recover the relative WB scales for other WBS. We will fix the WB scales to [1 1 1] of the WB which the current BTF is in. Please change the current BTF if you want another WB to be fixed. Before re-computing the scales, do “reload” to initialize the WB scales first.
6.2 Select the points to compute the space transformation
The valid range for this is changed to [50, 200]:

Select all loaded BTFs and uncheck all outlier groups (the valid range already get rid of most of the outliers):

6.3 Compute and check the results
Press button “update Ts” to compute the space transformation matrix:
The Space transformation and the WB scales of current BTF are shown. You can check other WBs by changing the current BTF.

Check the “T=” to apply this transformation to the data plotting; also change the valid range, so you will see the result plotting as below:
This is the plotting of color points of image X of the BTF image pair. If you want to see the plotting of the second image Y, check “Y” in the “Img Pair” panel.

You will see the plotting:
7 Compute parameters of Warping Model

Keep the current state unchanged:

- **Valid range**: [5, 253];
- **No outlier group** is checked;
- **All the loaded BTFs** are checked (these loaded BTFs are purposely selected: various WBs, well distributed colors and brightness levels.)
Change current model to “Warp Model”, and then press compute. Wait for it to complete the computation. It will take some time. You can read the status in Matlab Command Window:
Filtering duplicated points...
  11641  left: 7839
Elapsed time is 0.836896 seconds.
Elapsed time is 22.702397 seconds.
  Init samples 3841 out of 11641
Some selected samples still causing high errors.
  add 1212 more samples.
Elapsed time is 11.029991 seconds.

New iter: 5053 of 11641
Some selected samples still causing high errors.
  add 202 more samples.
Elapsed time is 22.242356 seconds.

New iter: 5255 of 11641
Some selected samples still causing high errors.
  add 1 more samples.
Elapsed time is 24.358406 seconds.

New iter: 5256 of 11641
Some selected samples still causing high errors.
  add 0 more samples.
Elapsed time is 23.492682 seconds.

Warping Err(jpg2raw): (6.373837e-004, 4.437979e-004, 9.370717e-004)
Elapsed time is 2.254121 seconds.
Warping Err(raw2jpg): (1.308057e-003, 5.758582e-004, 1.532545e-003)
Elapsed time is 23.929141 seconds.

Check the “Model applied” to see the plotting result.
Save those parameters by pressing “**save model**”; the parameters will be saved in text files. Relating to the format of the records, please refer to the readme file about model parameters on our project page.

End of the Example

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