ISP Tuning Guide

Confidential

Revision 0.008

2024/05/19

altek Corporation

Revision History

REVISIO	DATE	DESCRIPTION	AUTHOR
0.001	2023/08/2	Initial draft	Zeno Kuo
0.002	2023/08/29	Update format	Jim
0.003	2023/08/29	Update sharpness section	Shawn Peng
0.004	2023/09/07	Update ER section	Peggy Wang
0.005	2024/01/25	Update BayerCodec section	Allen Wang
0.006	2024/01/26	Update ER section	Peggy Wang
0.007	2024/03/20	Update NRE scaling factor description	Sinder Wang
0.008	2024/05/19	Add appendix about color tint	Sinder Wang

Contents

1. Terms and Abbreviations.

This chapter lists and defines terms and abbreviations used throughout this document.

ABC	Auto Bad Pixel Correction
AD gain	analog and digital gain
AE	auto exposure
AFD	anti-flicker detection
AWB	auto white balance, including R, G, B gain value
ASharp	Adaptive Sharpness
BCCM	Blended Color Correction Matrix
BDS	Bayer domain scaler
BLC	Black Level Clamp
BV	brightness value
CCB	Cb Cr 444 Blur
CCM	Color Correction Matrix
CFAI	Color Filter Array Interpolation
CFR	Color Fringe Reduction
CS	Chroma suppression
DTC	dynamic tone control
ER	edge refine
FW	Firmware
GTE	Geometry Transformation Engine
GTM	Global Tone Mapping
HW	hardware
IQ	Image Quality
IRP	Image Reproduction Pipeline
ISP	Image Single Processor
LCE	Local Contrast Enhancement
LSC	Lens shading compensation
LTM	Local Tone Mapping
MWB	manual white balance
NRE	Noise Reduction Engine
OB	black offset
OTP	One-Time Programmable memory
PP	post processing
SW	Software
TNR	temporal noise reduction
WDR	wide dynamic range

2. Introduction

This document provides the description of functions and describes the procedures of ISP tuning for AL2500.

1. Environment requirement of the AL2500 tuning tool

The internet should be connected. Otherwise tuning tool wouldn't be open correctly. The following list the suggestion environment, Inter Core i5 or higher-level CPU with at least 8G RAM, and Microsoft Windows 7/8/10 64bit install visual studio 2010 or visual studio 2013 C++ redistributable package with .Net Framework 4.7.2.

2. Supporting functions

Pipe configuration, LSC, ABC, Bayer crop (WOI), TNR, SNR, BLC, CFAi, GTM, RGB2YUV, NRE, LTM, CCM, Tone, Chroma Suppression, Sharpness, and Post Processing.

3. Support Pipelines

The pipeline of tuning procedure from top to bottom.

Fig. 2-1 AL2500 Pipelines

3. Overview.

When execute AL2500 tuning tool, you need to create a new tuning project by enter the project setting page to set the image information. And please click the "Update" button on the upper left to update the settings. Once update the image information or update the tuning parameters, you could save out two project files through 'save project file' button in project column. One is tuning project (.json) which describing the project information and another is a folder containing the parameters of each ISP blocks. If there is already an existing project, you can press 'load project file' button to load the existing project (.json).

In order to start simulation, please entry the ISP setting page, press the "Load" button in the "Image" tab to load a Raw file for image quality simulation. Note that the format of the loaded file must be consistent with the format setting in the "Project Setting" page. Then select the "Condition" tab (錯誤! 找不到參照來源。), input the metadata of raw, and press the "Update" button. The tool will take a while to process the raw image. AL2500 also provides the ISP information which list the Image Quality (IQ) parameters in json format (Fig 3.2).

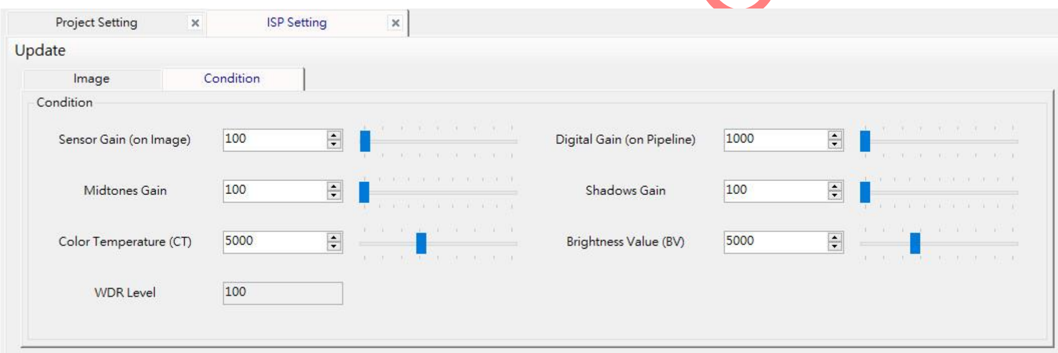


Fig. 3-1Meta data in condition page

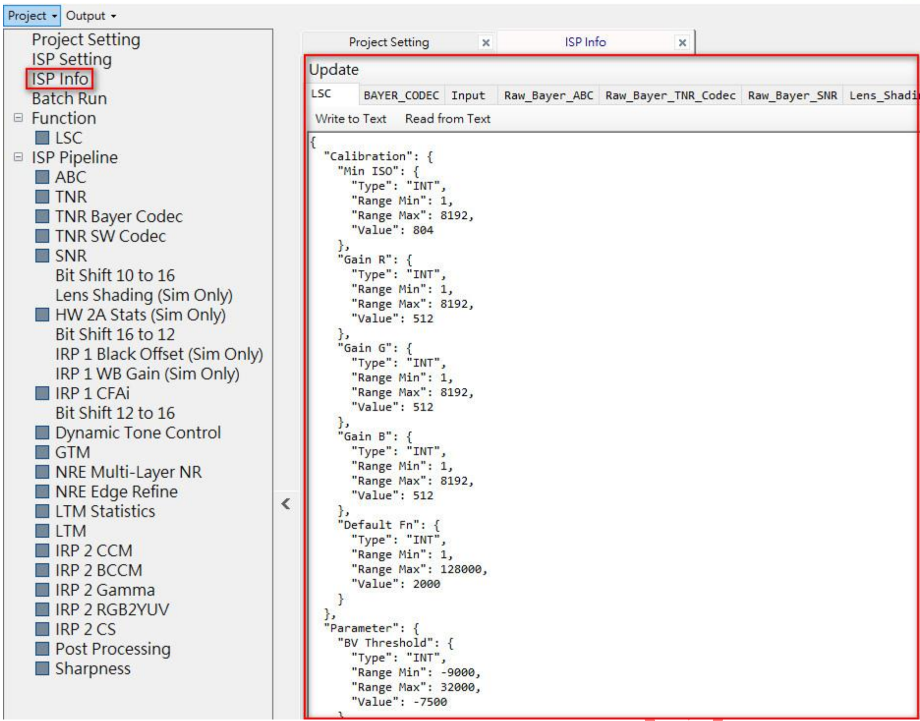


Fig. 3.2 ISP info page

3.1. Workspace overview

Please refer to Fig 3.3, there are four workspaces in AL2500 tuning tool.

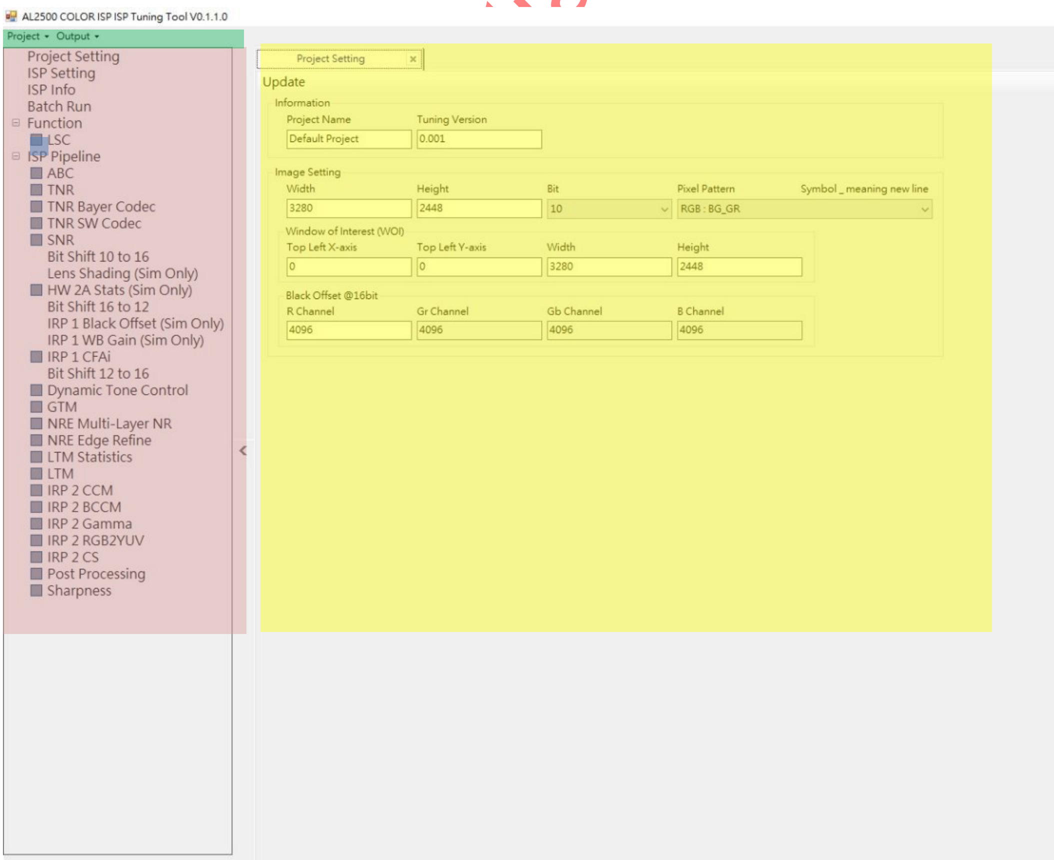


Fig. 3.3 Workspace of GravityXR tuning tool

1. **Project and output strip**: In the green region in Fig. 3., is for saving/ loading the project file (.json) including off-line simulation settings and binary file (.bin) which is applied to update ISP parameters to pipeline.

2. **Modules list**: In the red region in Fig. 3., including buttons for setting project file, loading input image, and lists of all ISP modules. User can select functions in modules list, and shows the features of the functions in modules page. Including 5 sections:

- **Project setting:** set project name / version, input and output format.
- **ISP setting:** load input image file or simulated data which be dumped for TNR batch run, related with shooting scene.
- **ISP Info:** list image quality parameter in json format.
- **Batch run:** runs simulation in batch. Results of full pipeline, stage output, and TNR simulated file (.dat) can be created in this function.
- **Function:** LSC function.
- **ISP pipeline:** shows GravityXR pipeline. The status of each module is indicated by the color of checkbox

3. **Status icons**: In the blue region in Fig. 3., legends indicate the module's status of current simulation. Descriptions of each icon is shown below:

- ■ indicates the parameters are the same as default setting.
- ■ indicates the parameters of loaded project file are updated.
- ■ indicates the parameters of loaded project are different from default setting.
- ■ indicates the module is disable in simulation.

4. **Module page**: In the yellow region in Fig. 3., shows tuning pages of modules selected in modules list. Users can close page by clicking ☒ on the right of module's name, and updates parameter to ISP by clicking 'Update' button in the top-left of module page. If parameters aren't updated before being closed, parameter updated last time when users open it again.

3.1.1. Project setting.

Open project setting page to sync the basic sensor setting for project simulation. It contains four parts:

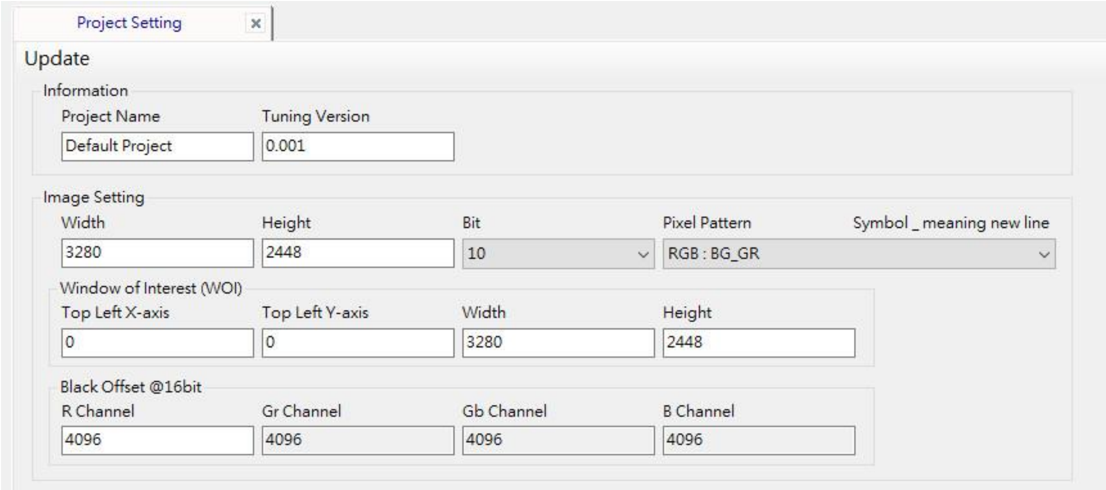


Fig. 3.4 Module page of project setting

1. **Information:** user can define a project name and a tuning version (range 0.001~999.999) to discriminate projects. These values will be shown in the filename of project file and binary file. The module number and the tuning version will be recorded in the first and the third values in binary file's IQ version.

2. **Image setting:** properties of input raw are set here, e.g., image width, image height, bit-depth (8-/10-bits for normal pipeline), Bayer pattern, and black offset. Please note that these setting are only for off-line simulation.

3. **Window of interest (WOI):** user can set a WOI by filling its top-left coordinate (axis X is horizontal and axis Y is vertical), width and height. These values should be 4-base. We suggest user to check the ratio of WOI with the scale-down resolution of Bayer scaling. Please note that these setting are only for off-line simulation.

4. **Black offset:** users need to synchronize the black offset of input raw with 16-bit base. Please note that these setting are only for off-line simulation.

3.1.2. Preview and display

There are icons on the top of preview window (Table 3.1) that help users to check the result of current refinement.

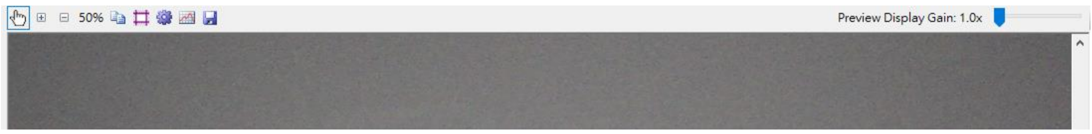


Fig. 3.5 UI in preview window

Table 3.1 Summary of icons in preview window

Icon	Tag	Usage
	Move	Left-click on the displayed image and drag it to the region you want to check.
⊞ ⊟ 100%	Zoom In / Out	Left-click on the displayed image to zoom in/out to check details and edges.
	Compare	Compare the result of current setting with the setting which is previously updated to ISP.
	Selection	Select regions for “Data Analysis”.
	Setting	Set the format of selection: 4 region arrangements in “Type” with 3 margins in “Interval” are provided.
	Data Analysis	Please refer to Data analysis
	Save BMP	Save the displayed image on preview windows in BMP format. Users also can save the input/output of selected module in its stage format by “Saving Type (T)” in “Save Image” page
Preview Display Gain: 1.0x	Preview Gain	Applied in preview window to let the displayed image get brighter. It helps users to check the effect of tuning more clearly, especially for tuning modules before Gamma.

3.1.3. Data analysis.

“Data Analysis” is a tool for measuring properties of regions, selected in preview window. Please note that these properties are analyzed in 8 bits domain (displayed image). Here are steps to imply data analysis:

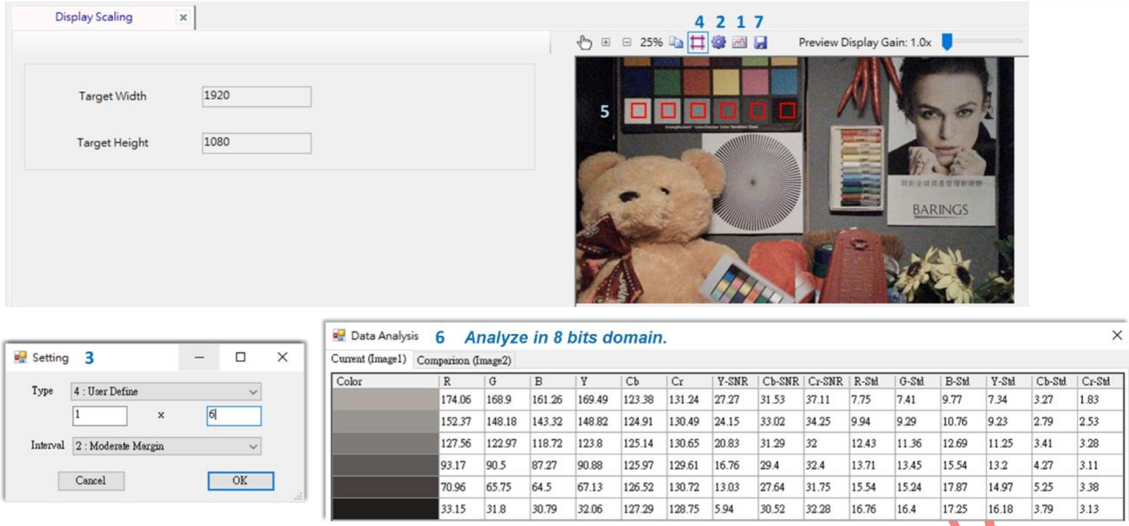


Fig. 3.6 Steps for data analysis

Step 1.	Click to open the window of "Data analysis".
Step 2&3.	Click to arrange regions according to your application.
Step 4&5.	Click to select regions in preview window.
Step 6.	Check properties show in the window of "Data analysis". "Current (Image 1)" shows the result of current setting, and "Comparison (Image 2)" shows the result of setting that previously updated to ISP.
Step 7.	To save the simulation stage output.

3.1.4. Simulation

Since the windows version tuning tool is developed based on the .NET architecture. In order to achieve correct simulation results, please aware that it is possible to open tow tools of the same version in the windows environment at the same time and operate properly, however if two tools with different versions are opened at the same time, there may be unexpected simulation results. And when multiple tools with the same version are opened at the same time, only one tool can perform batch processing one time.

4. Automatic LSC.

By calibrate sensor and generate CT table to achieve automatic compensate LSC in different ambient color temperature.

4.1. Sensor Calibration.

In LSC page, please input the following three information before sensor calibration: calibration version, sensor name (constrained to 20 ASCII words), and module house name (constrained to 20 ASCII words). Due to the different behavior of sensor module, you need to calibrate golden module by the following steps.

Step 0. Environment setting.

Light source box, for example LSB-111, is required to setup light source to D50 (5000 ± 200K, 500 ± 50lux). And in order to pick master sensor module, the more modules are better.

Step 1. Capture settings.

- Format: unpack raw
- Flip\mirror: off
- VCM: infinity
- AD gain: 1x
- Distance: <1 cm between camera module and light box. Keep in straight
- Resolution: full
- Light box: D50 (5000 ± 200K, 500 ± 50lux)

Step 2. Each module is required to capture 4 images (index: 1, 2, 3, 4) and each with the following exposure setting.

Image_1: 0.5 sec

Image_2: exposure time is calculated by module Fn and light box Lv from calculation page (Fig. 4.3)

Image_3: 0.005 sec

Image_4: Adjust the exposure time manually to get 600~640 (10bits) in G channel including black offset at the center 1/5 of raw image. (Fig. 4.4)

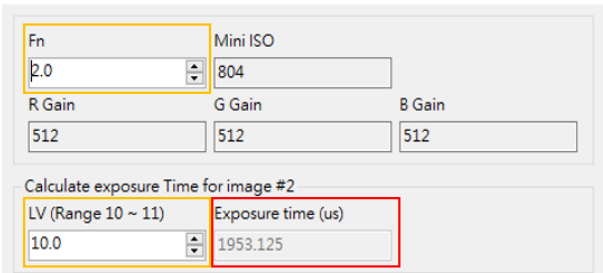


Fig 4.3 Input module's Fn and lightbox's LV (yellow), exposure time will be calculated (red).

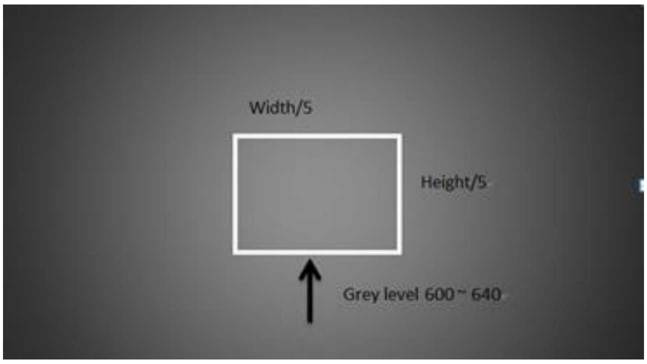


Fig 4.4 Measure gray value at 1/5 raw.

Step 3. Create a root folder, and sub-folders containing 4 raw images of each module. The naming rules of each raw image should include the index suffix. (Fig 4.5)

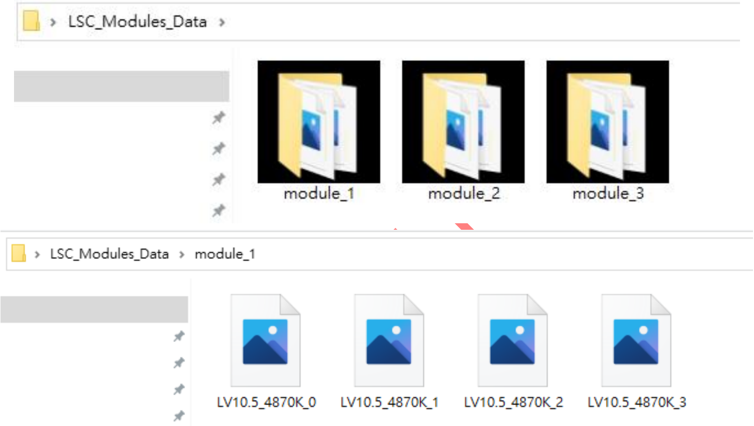


Fig 4.5 (top)creates root folders for each module, (bottom) put raw images captured by each module with index suffix naming.

Step 4. Click the "Pick Master Camera" button and select the root folder to get the calibration result and get the information showed in pop-up window.

Be aware that there will be an error message, refer to Fig 4.8, when input image does not meet the requirement. After finishing golden module calibration, click "Update" to save calibration information.

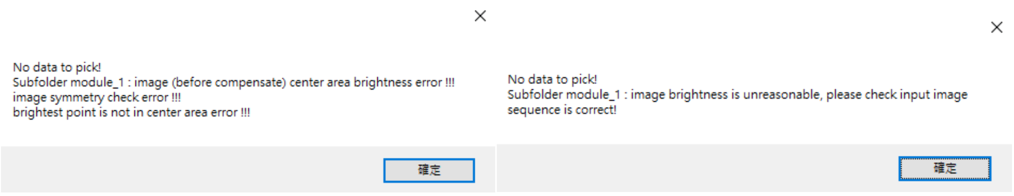


Fig 4.8 Error message of pick master module.

4.2. Calibrate CT shading table.

The LSC tuning file contains 5 CT shading tables, and each table records its color temperature. The following section shows the required environment and how to set the basic shading table in the tuning file.

1. Environment requirement:

light box or light source box is needed to satisfy multi color temperature environment, recommend are 2400K, 3000K, TL84, CWF and 5000K(D50)

2. Calibrate basic shading table:

Step 1. Get uniform raw image which gray level of g-channel of center 1/5 area is between 600 to 640 from 1x sensor AD gain and use diffuser when needed. Please make sure that there is no other ambient light source except light box or light source box. The captured image could be like Fig 4.11. Repeat Step1, get shading raw from the recommend light source, 2400K, 3000K, TL84, CWF and 5000K.

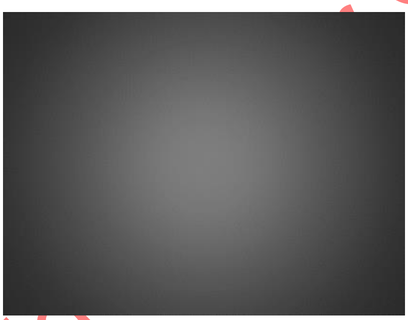


Fig 4.11 captured shading image.

Step 2. Refer to Fig 4.12, input the CT value in Map page and click the calibration button to load the relative raw image to calibrate basic shading table and repeat Step2 to calibrate all CT images from Step1. Be aware that there will be an error message when input image does not meet the criteria.

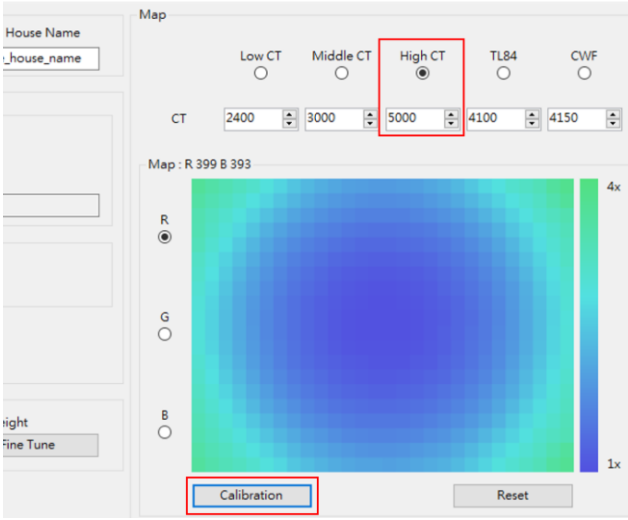


Fig 4.12 Calibrate CT shading table. By fill in the CT value and load the relative raw image from calibration button.

Step 3. After calibrating 5 CT shading tables, “Fine Tune” button next to calibration button will be shown. You could enter fine tune page to start fine tune. First to  load the raw image and you could calibrate white balance gain by reference Fig 4.15 or manually input WB gain. Depends on Fig 4.16 interpolation ratio, fine tune R, G and B channel table (Fig 4.17) between interpolated color temperature. For example, to adjust R channel in the corresponding CT to get the reddish calibrated result (Fig 4.17).

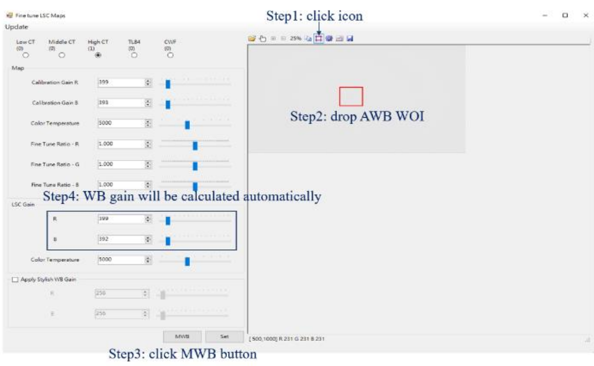


Fig 4.15 Manually calculate white balance gain SOP.

Fig 4.16 interpolation ratio of each table.

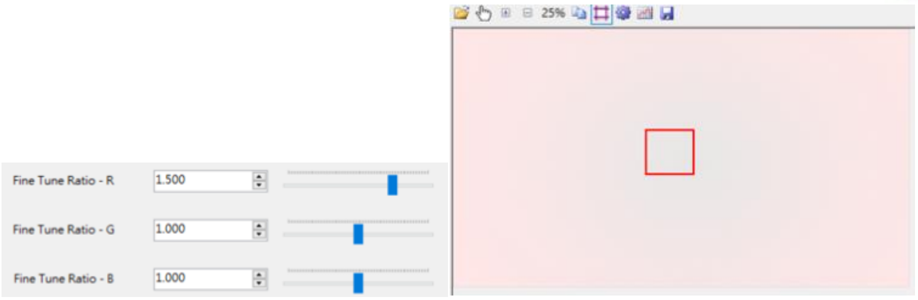


Fig 4.17 (Left) R, G and B channel table, (right) adjust R channel to get reddish result.

4.3. Reduce compensation.

Fig 4.18 shows reduce compensation feature in LSC page.

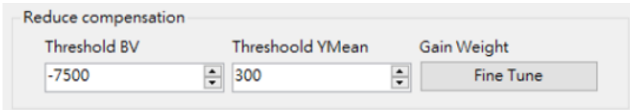


Fig 4.18 Reduce compensation setting.

When ambient luminance is less than the 'threshold BV', all the ratio of shading compensation gain will be set to 1 which means no shading compensation. And similarly, when compare input image Y-mean with 'threshold Y mean'.

Enter fine tune page by clicking 'Fine Tune' button, you could adjust decreased gain curve (1024 base) where the x-axis means input ISO, and y-axis means decreased gain ratio. For example, in order to avoid high ISO noise in the Fig 4.19 when input ISO = 100, down ratio = 1024 / 1024 = 1 which means no decrease, and if input ISO = 2800, down ratio = 256 / 1024 = 0.25 which means the gain value in LSC table will multiply 0.25.

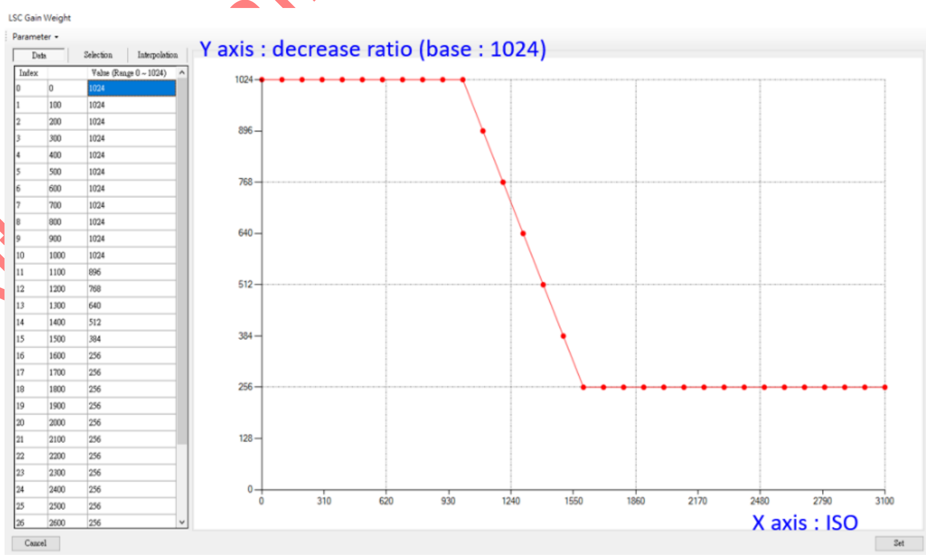


Fig 4.19 Decreased gain ratio curve.

4.4. Criteria setting

Not recommend adjusting criteria setting, unless the module is not evenly enough. By entering the 'calibration criteria' which next to 'update' button and check the box of 'Shading Criteria". You could adjust the vignetting percentage, color shading percentage, central intensity range which means the brightness of the center of raw and symmetry threshold which means the balance of four corners. Or you could reset to default by check the 'reset to default' box and press 'apply' button.

Note 1.

Vignetting percentage: divide image to 5x5 blocks and calculate Y values of 4 corner's block and center block. The vignetting percentage defined to be the smallest percentage ratio of Y over center block.

Note 2.

Color shading: first to calculate the R/G, B/G, and R/B value and then calculate the difference ratio of these 3 factors of each block over center block.

5. ISP pipeline tuning

5.1. Introduction of ISP pipeline tuning

In this section, tuning principles and common tool components are introduced.

5.2. Auto Bad Pixel Correction (ABC)

Auto bad pixel correction (ABC) module deals with defective pixels which cannot be calibrated or found in advance such as hot pixel. In general, this kind of pixel is performed in single or cluster-wise on image. Besides, the case of bad pixel in ISP includes white bad pixel (WBP) and dark bad pixel (DBP) in Bayer domain.

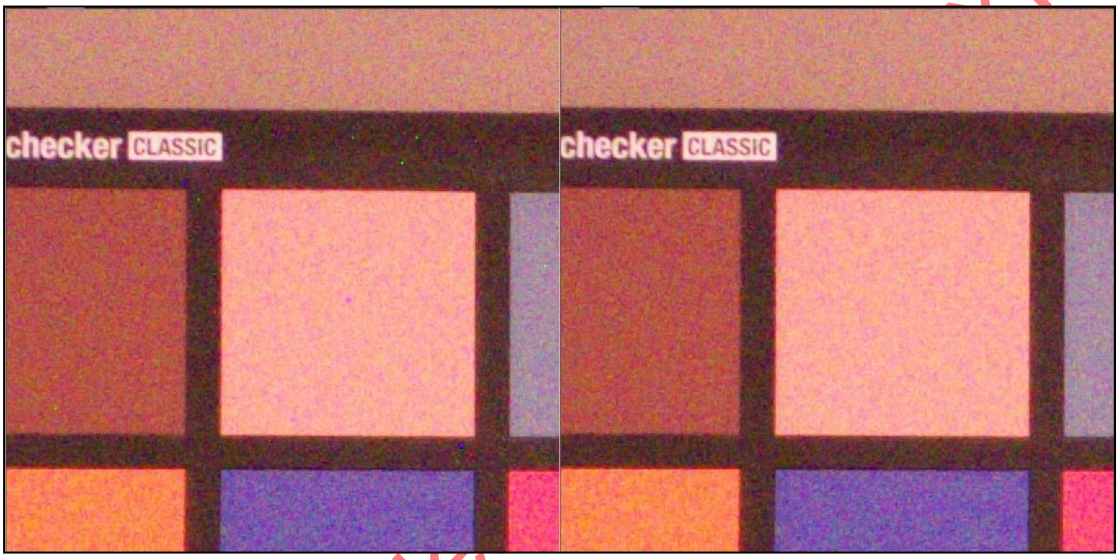


Fig. 5-1 : (Left) ABC off, defected pixel on image. (Right) ABC on, defected pixel removed.

5.2.1. Tuning process:

■ Tuning order: Threshold → Cluster → Preservation.

■ Parameter setting (recommend):

- Threshold: Level 6-11. (WBP/DBP)
- Cluster: Level 1-4.
- Preservation: Level 4-6. (WBP/DBP)

5.2.2. Threshold

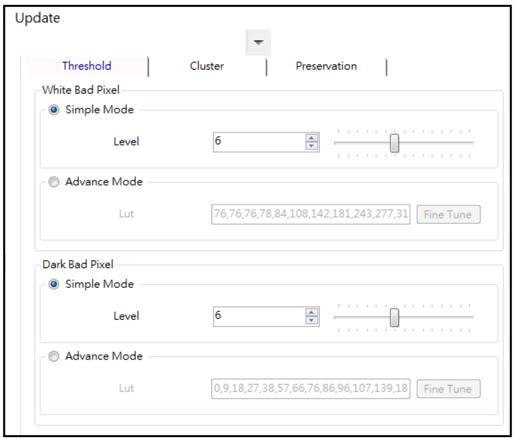


Fig. 5-2 Tuning UI for ABC Threshold

■ Define the threshold of outlier that a pixel will determine to bad pixel.

■ Tune for WBP (white bad pixel) and DBP (dark bad pixel) in separate.

■ Level Range: 0-14; default= 6.

■ Low-level means only pixels with very high peak in signal be detected as bad pixel; as level increase, the pixel with middle or low peak also falls into outlier and detected as bad pixel. (Fig. 5-3)

Fig. 5-3 : (Left) Original Image. (Middle) Correct few of pixels in very high peak when tuning threshold with low level. (Right) Correct more pixels include middle or low peak in signal when tuning threshold with high level.

5.2.3. Cluster

Please refer to Fig. 5.4 the cluster page.

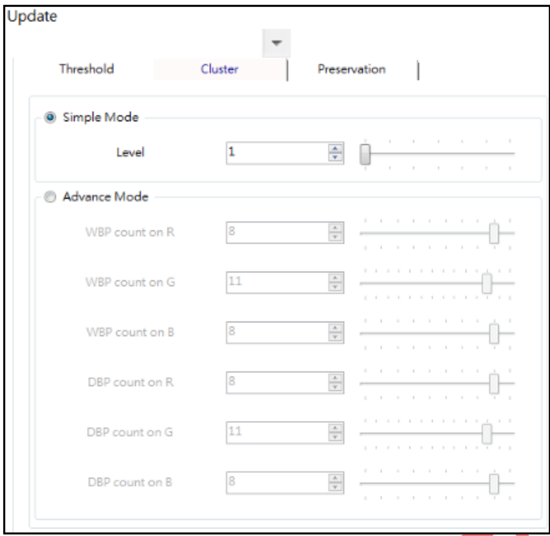


Fig. 5-4 Tuning UI for ABC Cluster

■ Control the cluster level for handling cluster-wise bad pixel. (Fig. 5-5)

■ Level Range: 1-7; default=1.

■ Enable to fine tune cluster parameter for R/G/B channel respectively in advance mode.

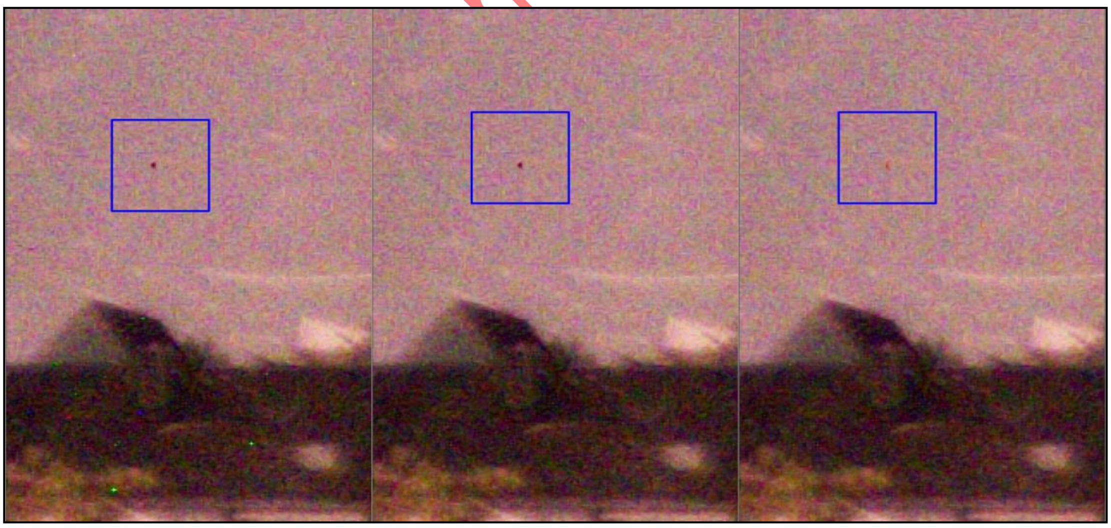


Fig. 5-5 : (Left) Original Image. (Middle) Unable to remove cluster-wise pixel with weak cluster level. (Right) Remove cluster-wise pixels after applying adequate cluster level.

5.2.4. Preservation

Please refer to Fig5.6. the preservation page.

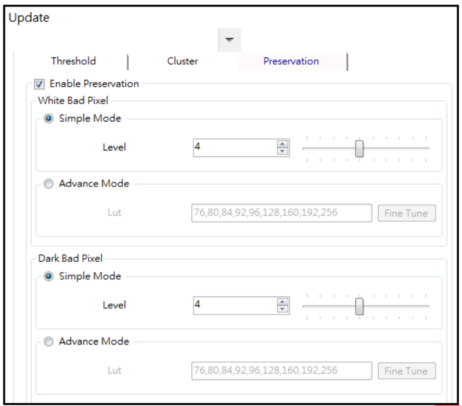


Fig. 5-6 Tuning UI for ABC Preservation

■ Use to preserve some bad pixels with false detection such as spot-like feature (ex: stainless brush). (Fig. 5-7)

■ Tune for WBP (white bad pixel) and DBP (dark bad pixel) in separate.

■ Level Range: 0-9.

■ Increase this level, more bad pixels originally with false detected would turn out to normal pixels.

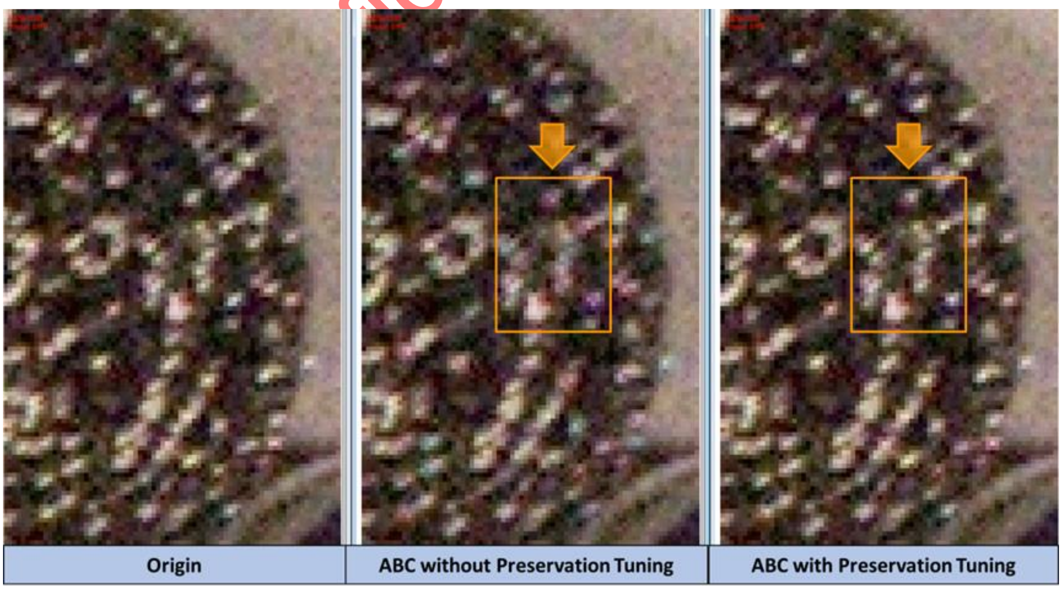


Fig. 5-7: (Left) Original Image. (Middle) Detail loss on spot-like feature when taking no preservation tuning. (Right) Keep more detail after preservation tuning.

5.3. TNR

The main goal of TNR (temporal noise reduction) is to decrease temporal flicker noise while keeping detail as much as possible. In addition, when videos have local motion or global motion, Good TNR tuning can try to prevent obvious ghost effect and de-noise temporal flicker.

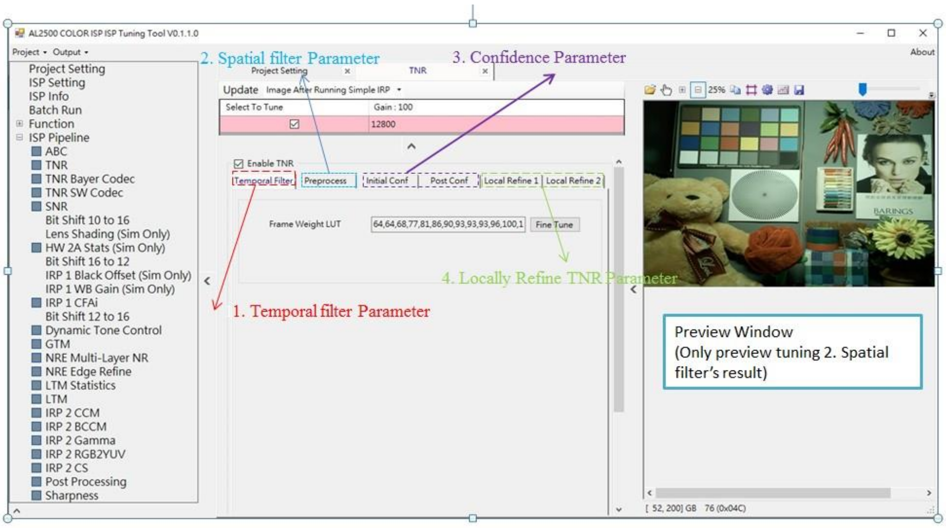


Fig. 5-8 Overview of TNR GUI

5.3.1. TNR Tuning Concept

- TNR's component
  - ☐ Temporal filter: Naive de-noise temporal flicker noise, but in motion region, this filter will generate ghost image.
  - ☐ Spatial filter: mainly use in motion region or when temporal filter's result isn't good. But this filter can't handle temporal flicker. And its de-noise type isn't good.
  - ☐ Confidence: decide using ratio of temporal filter or spatial filter.
  - ☐ Locally Refine filter:

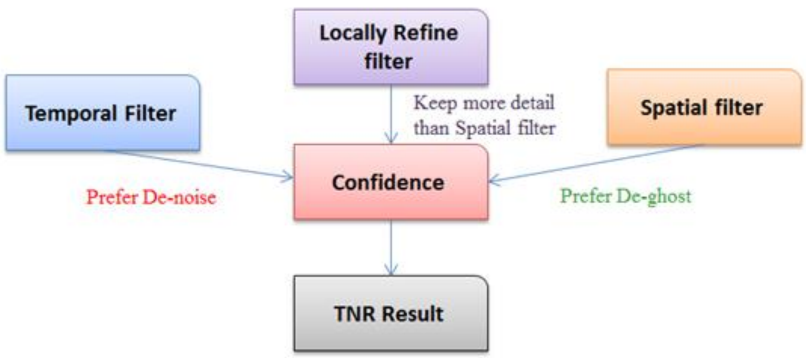


Fig. 5-9 TNR tuning flow

5.3.2. Tuning flow

- Tuning naive TNR(Temporal filter), see aggressively de-noise effect.
- Base on naive TNR effect to adjust spatial filter and local refine TNR. Avoid large gap between three filters.
- Adjust confidence map, use 24 color chart to get initial parameter of spatial filter & confidence map. Fine-tune initial parameter to get de-noise or de-ghost effect.
- Temporal filter's result is clean but in motion region might easily see ghost effect. Locally refine filter can keep more detail than spatial filter. But the result has more noise compare with temporal filter.

- Color chart calibration
  - Capture static 24 color chart's frame (Base on different ISO or noise level)(frame number > 8).
  - Select color chart regions(manual adjust), measure noise standard deviation & related intensity.
  - Use standard deviation & intensity to calculate linear curve fitting(y = ax + b, y is variance, x is intensity).
  - In dark area or light area, need to manual fine-tune because curve fitting have its limitation during extrapolation case.
  - Use motion scene to verify or fine-tune depend on user's need.

5.3.3. TNR Calibration flow

1. Load static raw image folder(>= 8 frames)
2. Select rectangle(manual adjust 4 corner)
3. Run calibration
4. Pre-calibration value will auto set in current UI

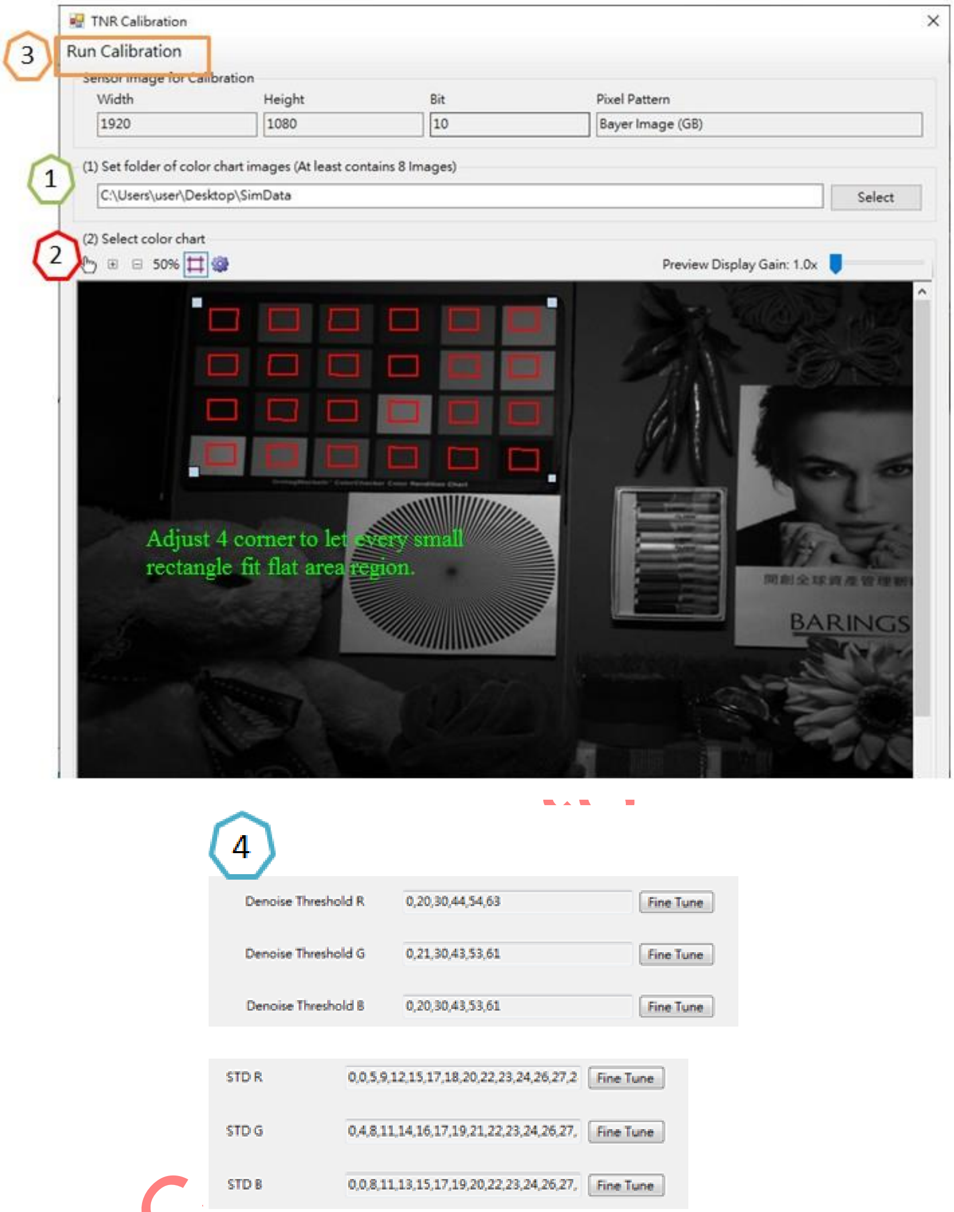


Fig. 5-10 TNR Calibration Step

5.3.4. Capture static raw sequence image

1. Put color chart in center region
2. Uniform lighting
3. Capture in certain ISO gain, ex: ISO 100, ISO 400……
4. Capture multiple raw sequence(>=10)

Fig. 5-11 Capture scene sample

5.3.5. Tuning stage UI

Please refer to Fig. 5.14 the tuning stage UI.

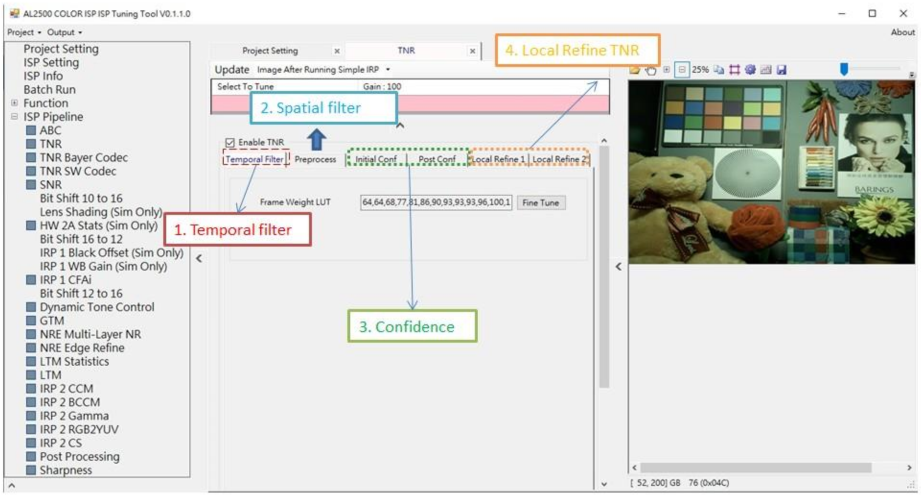


Fig. 5-12 Tuning step illustration

- Temporal filter
- Spatial filter

- Confidence
- Locally Refine TNR

5.3.6. Tuning – Temporal filter

- Decide previous frame's weight
- Range:[0~127]
- Guideline: start from 64, gradually increase previous frame weight. It is a convergent process. User can tune fast convergence or slow convergence. Frame weight large => use more previous image (clean, but easily get ghost)
- Frame weight low => use more current image(noisy, but can keep more detail)

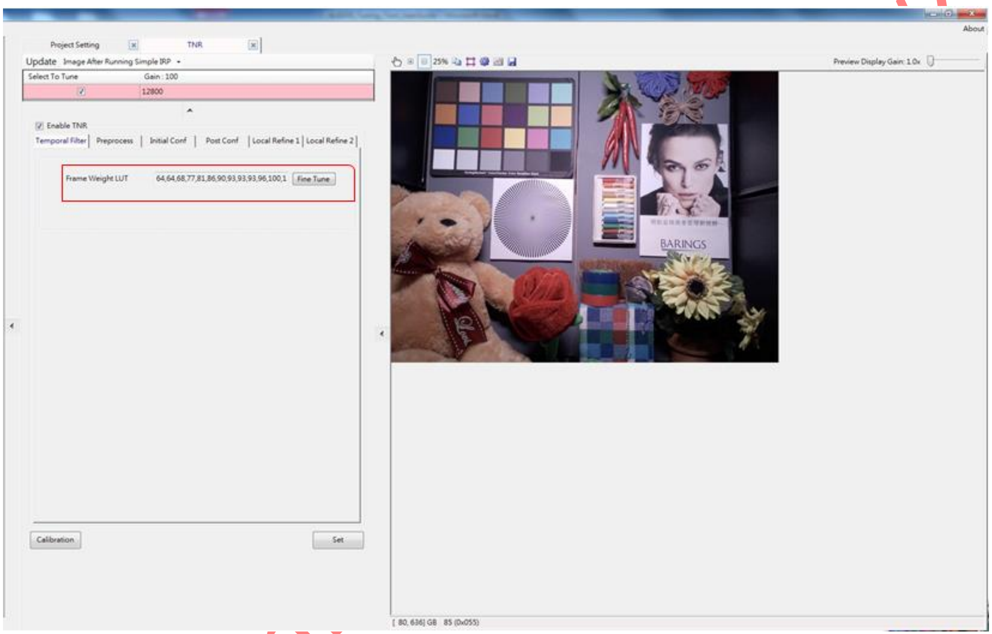


Fig. 5-13 Tuning temporal filter

- Sequence frame weight tuning

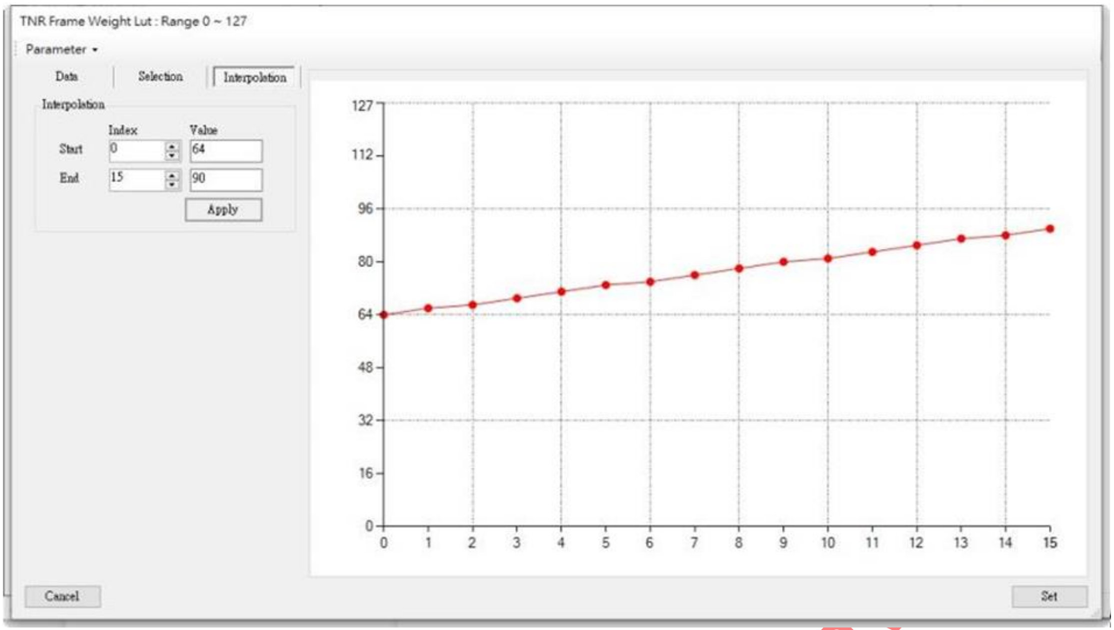


Fig. 5-14 Interpolation of sequence frame weight tuning

Ps: Avoid tuning previous frame ratio too large. When image become clean, Bayer codec will compress and de-compress unaccepted pattern (> 110)

5.3.7. Tuning – spatial filter

- Blending weight
  - ☐ Reference intensity
  - ☐ Control ratio of pure average intensity & original intensity
  - ☐ 0 : use more pure average intensity ; 127 : use more original intensity
- De-noise Threshold R/G/B
  - ☐ Use calibration step to pre-define initial threshold
  - ☐ Fine-tune threshold depend on image quality
  - ☐ Intensity node : 0, 128, 256, 512, 768, 1023
  - ☐ Set threshold large => de-noise strong
  - ☐ Set threshold small => de-noise weak
- Intensity Weighting
  - ☐ Define user wanted de-noise's intensity range
  - ☐ Intensity node range [0~255] [256~511] [512~767] [768~1023]
  - ☐ Set large => de-noise strong, but will look like average filter, detail will lose.

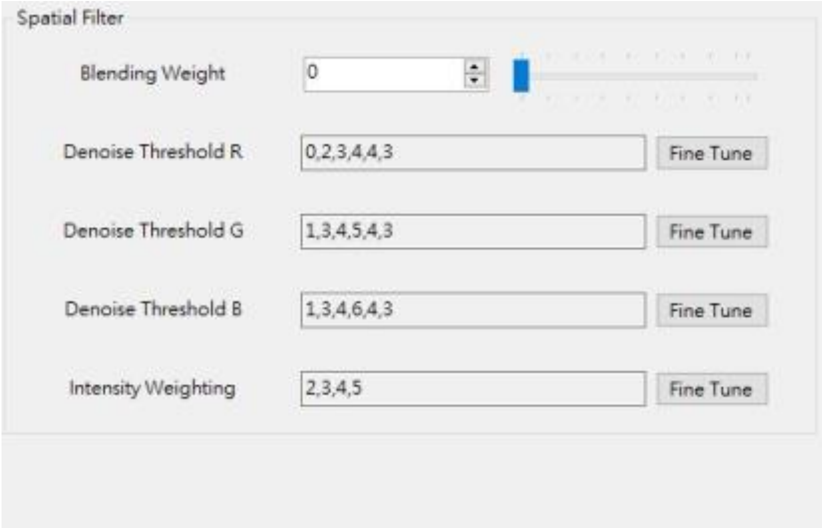


Fig. 5-15 Parameter of Spatial filter

Ps: Observe certain intensity
Noisy -> increase this related intensity de-noise threshold
Blur -> decrease this related intensity de-noise threshold
Increase intensity weight can also de-noise, but it is too aggressive. Need to careful tune this value.

- MAE(Edge map)
  - Apply different de-noise strength on flat area & edge area.
- MAE Kernel size
  - 3X3 is used for small image
  - 5X5 is used for large image & noisy image
- MAE Gain (MAE Preserve LUT)
  - MAE Gain directly apply on de-noise threshold R/G/B. It can increase de-noise threshold or decrease de-noise threshold.
  - Range : [0~63]
  - MAE node value : 0, 8, 16, 24, 32, 40, 48, 56, 63
  - 16 represent 1x gain, 32 represent 2x gain etc.
  - MAE value large => Edge region => Keep detail
  - MAE value small => might be flat area => De-noise

  Ex: In flat area (MAE node value near 0), increase de-noise strength.
  In edge region (MAE node near 63), decrease de-noise strength.

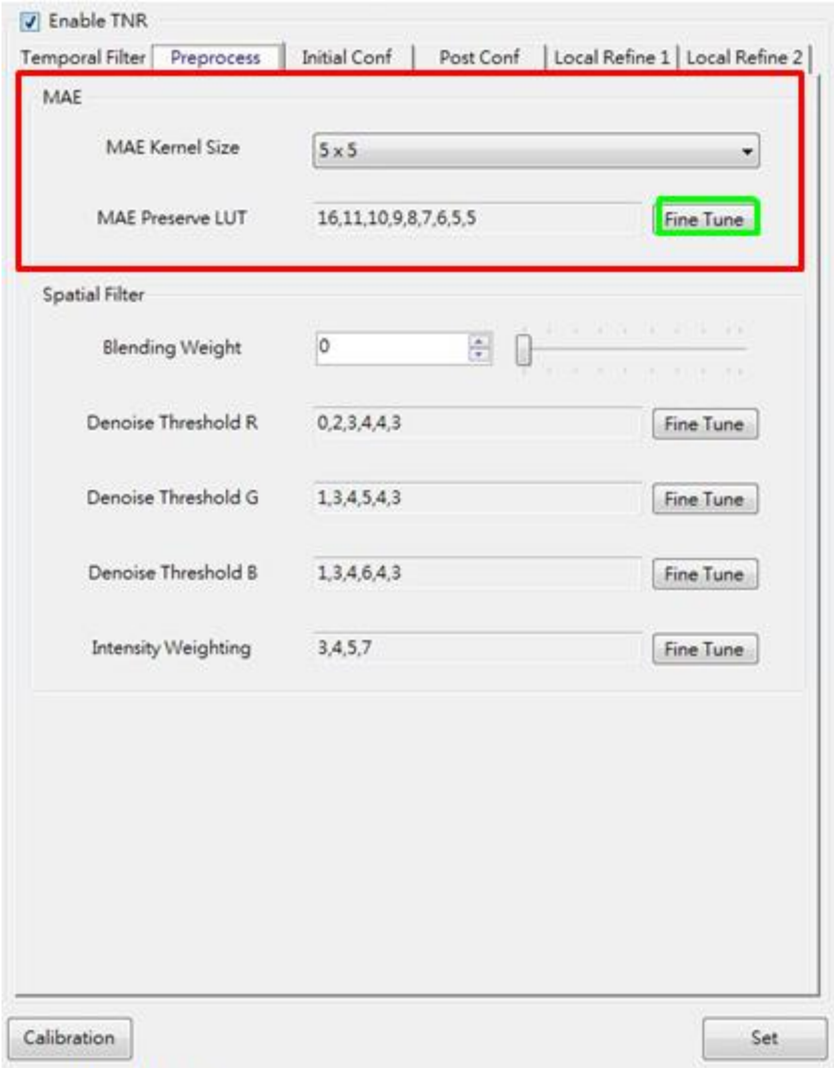


Fig. 5-16 Parameter of MAE (For Edge preserving Tuning)

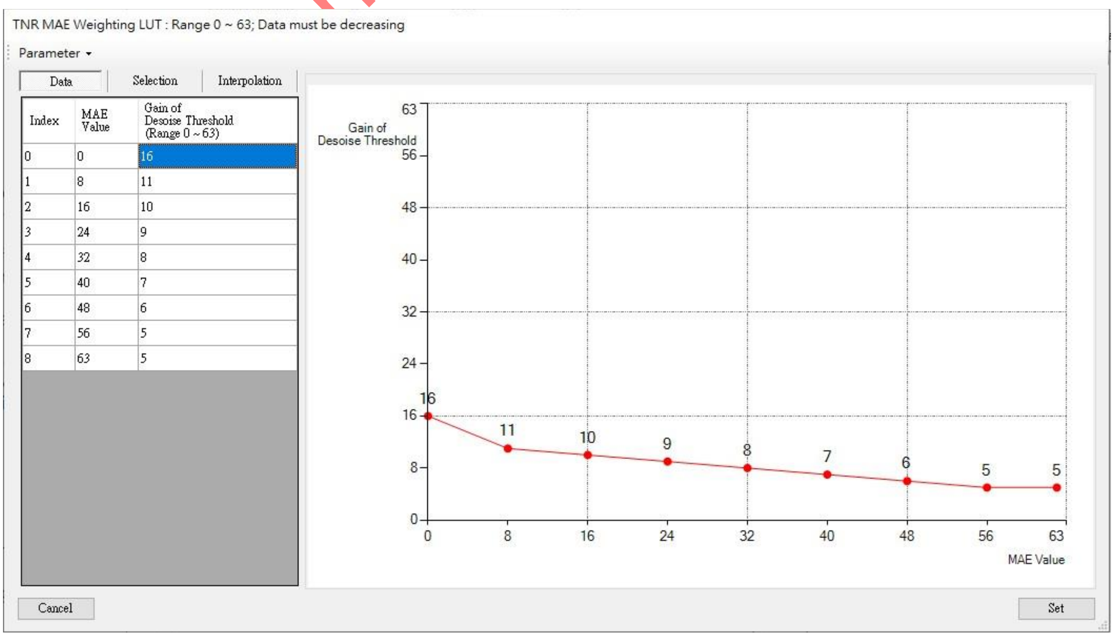


Fig. 5-17 MAE LUT

5.3.8. Tuning – Confidence

- Decide ratio of temporal filter or spatial filter or locally refine TNR filter.

- Confidence Mask size
  - 3x3 is for quite clean image
  - 5x5 is for noisy image
- Color difference
  - Mode 0 : Color Diff , pure pixel difference(for quite clean image) => de-ghost
  - Mode 1: Color Mean Diff, use N x N average, for noisy image => strongly de-noise effect.
  - Mode 2: Pre img – Cur img, use N x N average of current image, keep previous image unchanged. => slightly de-noise.
  - Mode 3: Pre img – Blend, use blending result of current image (with blur) & current image (original) via MAE value. => de-noise slightly weaker.
- Discount LUT
  - Use gain to shrink or enlarge color difference to avoid ghost or strongly de-noise flat area.
  - Apply on color difference's gain, 64 represent 1x gain.
  - Apply different gain on flat area/ Texture/ Edge.

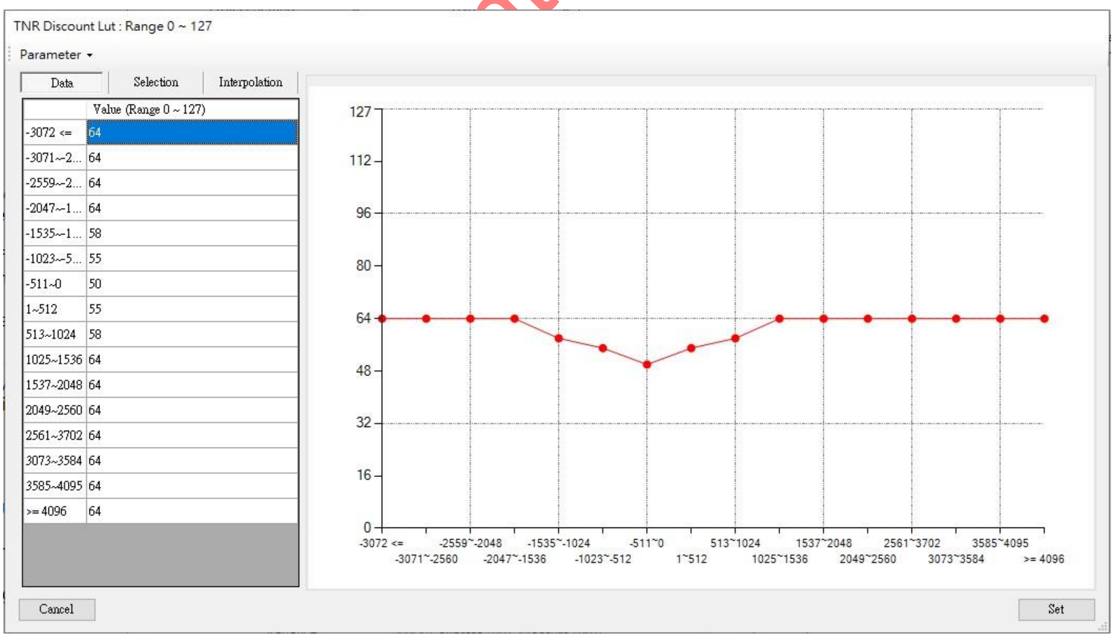


Fig. 5-18 Discount LUT

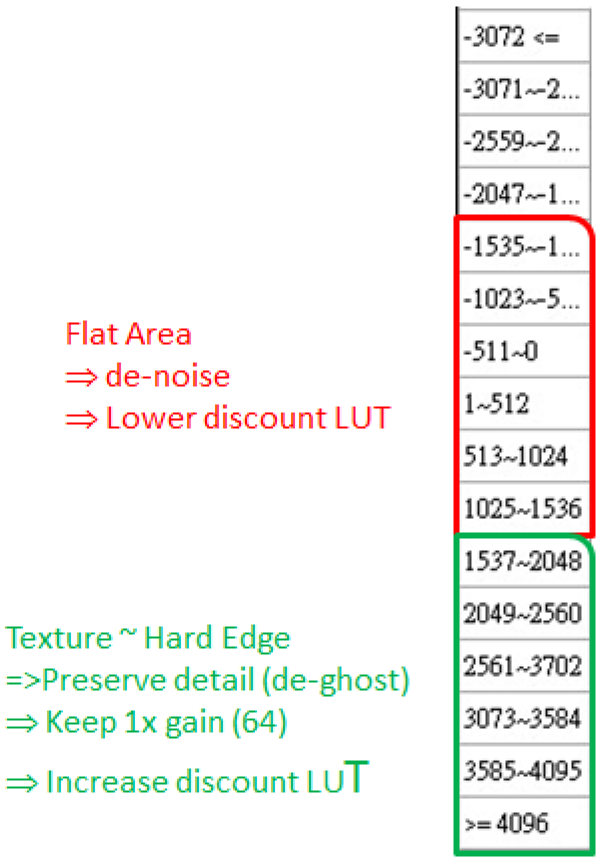


Fig. 5-19 Variance difference for discount LUT tuning

Variance

- ■ Lookup STD
  - □ Reference STD's intensity
  - □ Avg Intensity : for noisy image
  - □ MAE blending : for clean image
- ■ STD R/G/B
  - □ Decide R/G/B intensity's mapping STD value
  - □ Use pre-calibration mechanism to set, and fine-tune.
  - □ STD is large, confidence is high => easy for de-noise
  - □ STD is small, confidence is low => easy for de-ghost.
  - □ STD R/G/B intensity node : 0, 16, 32, 48, 64, 80, 96, 112, 128, 144, 160, 176, 192, 208, 224, 240, 256, 288, 320, 352, 384, 416, 448, 480, 512, 544, 576, 608, 640, 672, 704, 736, 768, 800, 832, 864, 896, 928, 960, 992, 1023.
- ■ Variance
  - □ Use calibrate variance or max(Calibrate Var, Measure Var)
  - □ Calibrate Var: user-defined value, use this mode & STD R/G/B, user can tune aggressively de-ghost style.
  - □ Max (Calibrate Var, Measure Var) : edge region will de-noise easily.
- ■ Anti-ghost
  - □ Color difference & Variance's gap. Use gap to find mapping confidence.

- ☐ Need to consider consistency.

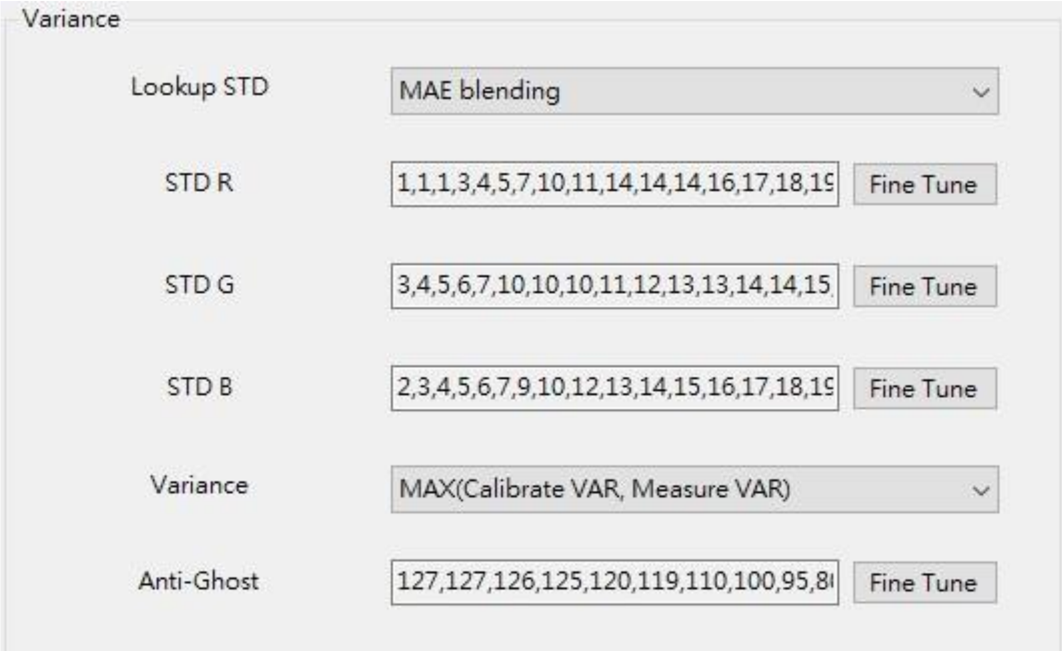


Fig. 5-20 Tuning Variance (STD) Parameter

Post Confidence

- ■ Post Processing Mask size
  - ☐ 3X3 & 5X5
- ■ Post Processing Mode
  - ☐ Min (Strongly de-ghost, but need to consider discontinuity)
  - ☐ Max (Strongly de-noise, notice ghost effect)
  - ☐ Blend Avg filter (Neutral method)
  - ☐ Blend min & Max (need to carefully tune Anti-Ghost LUT to balance)
  - ☐ Blend ori & min (Slightly prefer de-ghost) (recommend default)
  - ☐ Blend ori & max (Slightly prefer de-noise)
- ■ Scale / offset
  - ☐ Decide confidence's allowable range. Filter small value(offset) & enlarge confidence gap(Scale)
  - ☐ Scale * confidence – offset, clip into range [0~127]
- ■ Confidence Lower Bound/ Upper Bound
  - ☐ Use TNR's minimum/maximum ratio
  - ☐ Set Confidence Lower = 0 & Confidence Upper = 0 => Tune Spatial filter result or locally refine TNR filter result.
  - ☐ Set Confidence Lower = 127 & Confidence Upper = 127 => Tune Temporal filter.
  - ☐ In normal case, set lower bound = 0 & upper bound = 127
  - ☐ This parameter can let user quickly see each module's effect(Temporal / spatial/Locally Refine TNR)

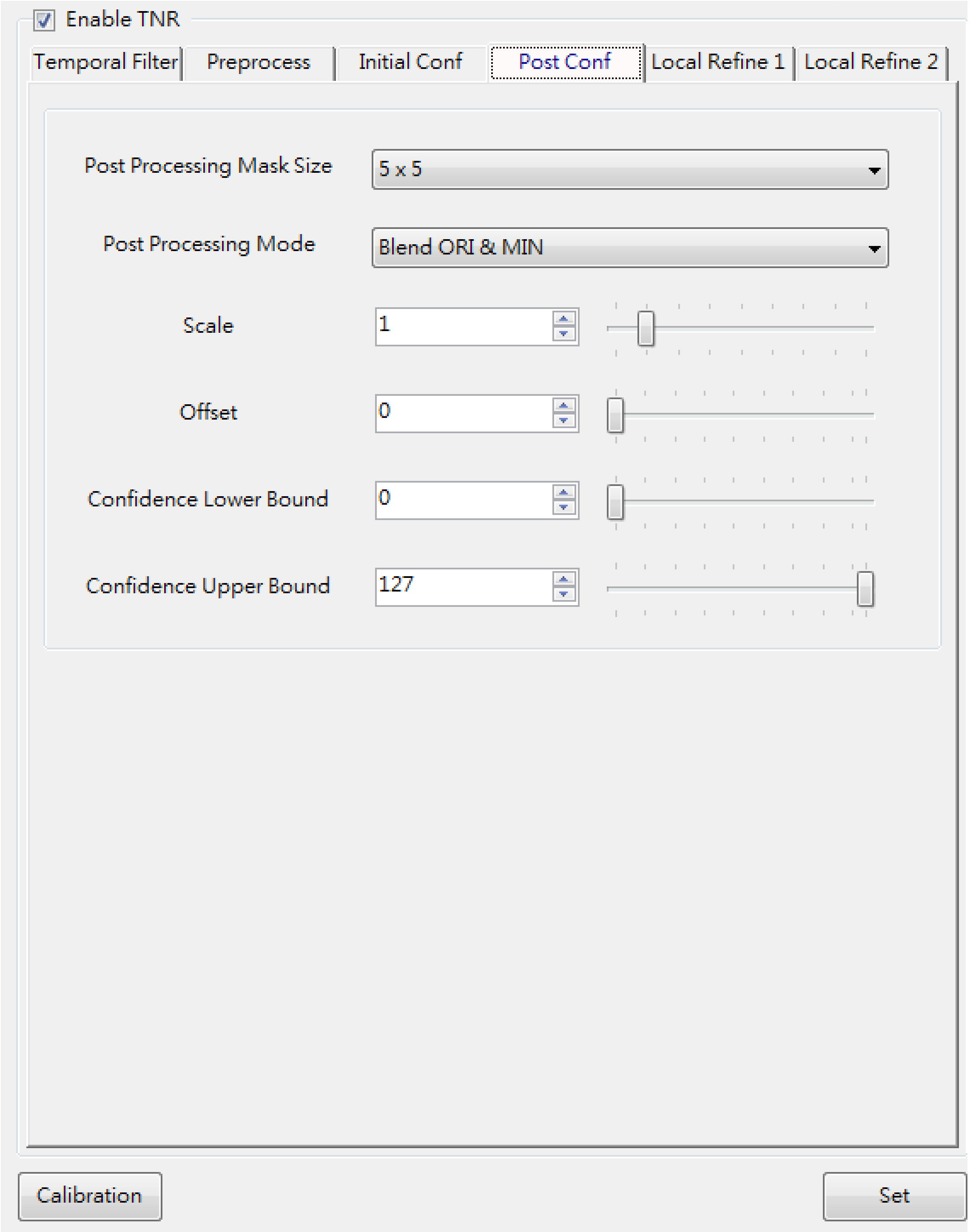
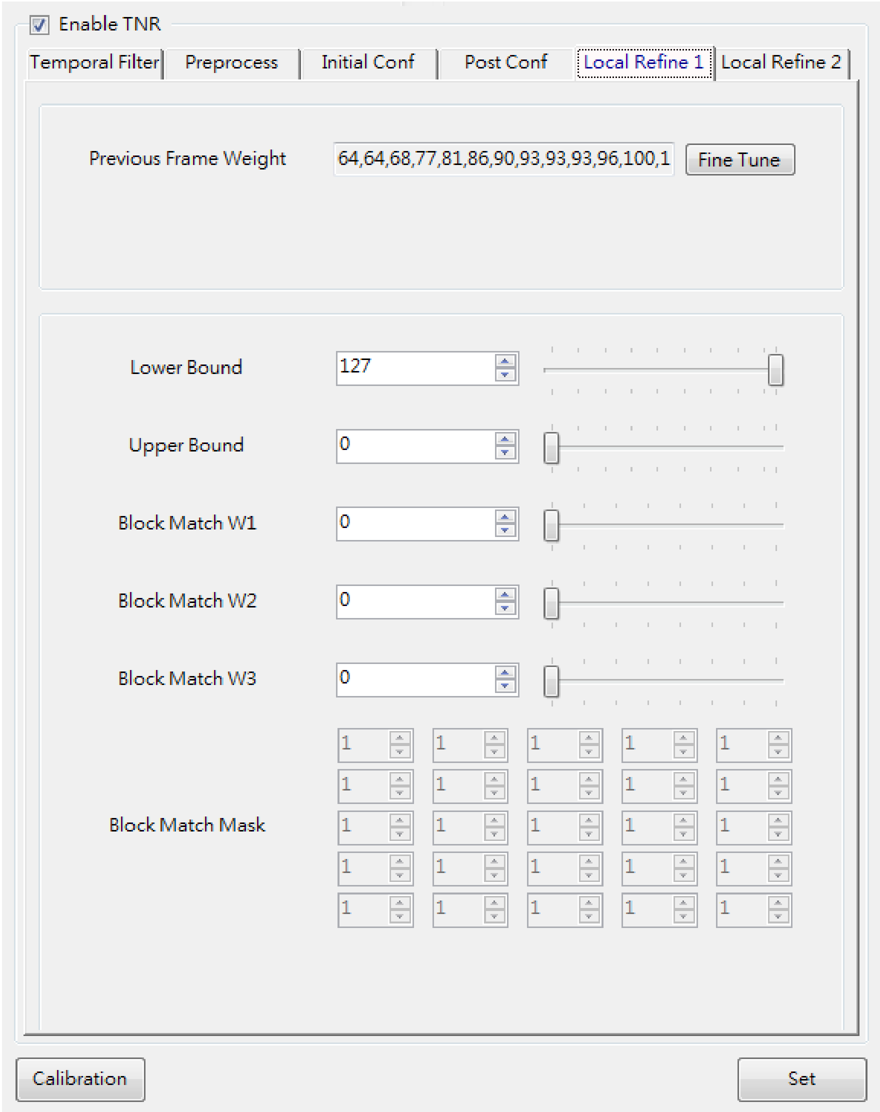


Fig. 5-21 Post Confidence parameter

5.3.9. Tuning – Locally Refine TNR filter

- Locally Refine TNR (LRTNR) can preserve more detail than pure spatial filter. We usually use this filter in motion region, and use pure TNR in static region.



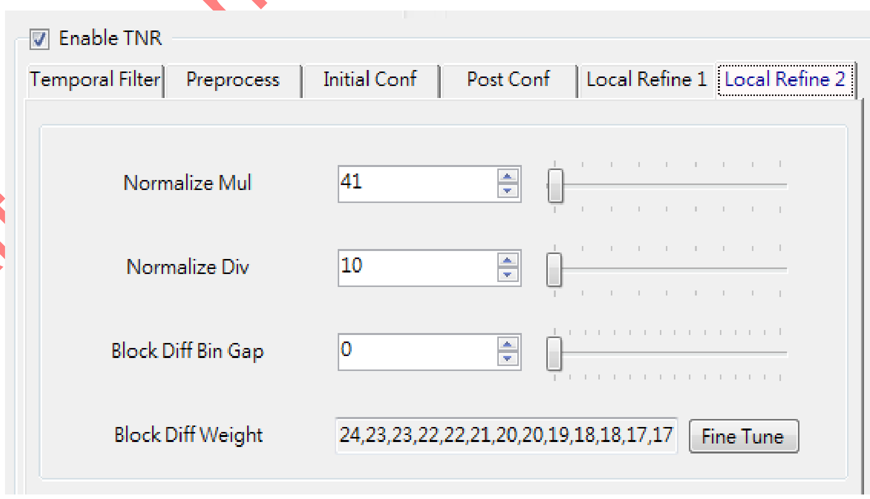


Fig. 5-22 Locally Refine TNR parameter. Top : Local Refine 1; Bottom Local Refine 2

- Previous Frame Weight
  - Locally Refine TNR's previous frame weight, this parameter is similar to Temporal Filter's Frame Weight LUT.

- Lower Bound/ Upper Bound
  - Use Locally Refine TNR's lower bound / upper bound.
  - Similar to confidence lower bound/upper bound.
  - Set lower bound = 0 & upper bound = 0 => don't use LRTNR result, it only uses pure TNR & spatial filter.
  - Set lower bound = 127 & upper bound = 127 => use LRTNR
  - Must meet criteria : Confidence Lower bound + Lower bound < 128
  - Must meet criteria : Confidence Upper bound + Upper bound < 128
- Block Match W1/W2/W3 (Block Match Mask)
  - For 5x5 patch match mask weighting.
  - W1/W2/W3 is power, the actual weight is $2^{w1 \text{ or } w2 \text{ or } w3}$, ex : set W1 = 0, weight is 1.
  - SH[0] = 2^{w1}, SH[1] = 2^{w2}, SH[2] = 2^{w3}

SH[2]	SH[2]	SH[2]	SH[2]	SH[2]
SH[2]	SH[1]	SH[1]	SH[1]	SH[2]
SH[2]	SH[1]	SH[0]	SH[1]	SH[2]
SH[2]	SH[1]	SH[1]	SH[1]	SH[2]
SH[2]	SH[2]	SH[2]	SH[2]	SH[2]

Fig. 5-23 SH is a weighting table for each pixel difference $|Src_i - Ref_i|$

- Normalize Mul/ Normalize Div
  - Block match normalization's hardware coefficient
  - Ex: if all weight is 1 in 5x5 mask, it will divide 25. We use 41 / 2^{10} ≈ 1/25. Normalize Mul will set 41 and Normalize Div will set 10.
  - Normalize Mul range: [0~8191] ; Normalize Div range : [0~13].
- Block Diff Bin Gap
  - Control patch difference's gap, ex: patch difference << 1, which mean difference 100 and 101 will map to the same weight.
  - Range : [0~15]
- Block diff Weight
  - Range : [0~24]
  - Actual weight is 2's power, block diff Weight is power.
  - Horizontal axis is block difference, ex: index 0 => Block difference is 0.
  - Block difference is large => two patch are not similar, their mapping weight need to set small.
  - Block difference range [0~31].

5.3.10. Batch run Tuning (Debug information)

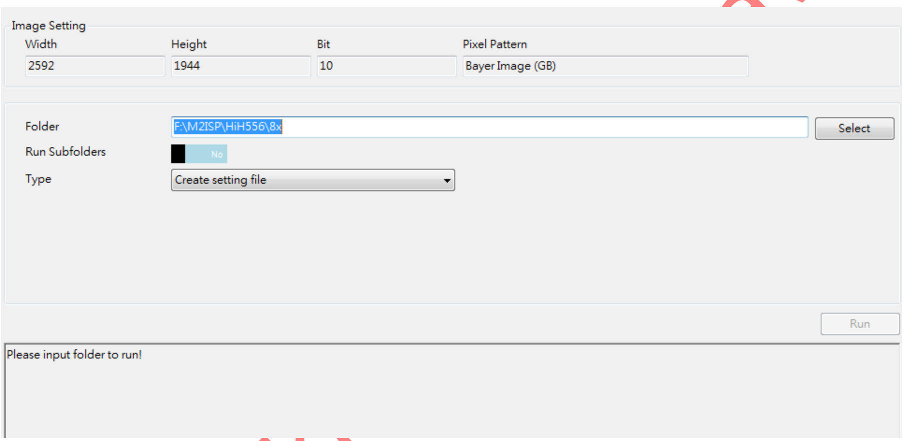
- Batch run tuning for TNR can generate debug information to help user fine-tune

TNR’s result.

- Step:
  1. Generate batch run of TNR simulate data
  2. Load sim_data for further fine-tune.

Batch Run Step

1. Select “Batch Run”
2. Load sequence of Bayer RAW
3. Generate setting files, (ex : ISP settings -> Condition(set parameter here))
4. After generating setting files, batch run TNR’s sequence result
5. Type : Consecutive frames
6. Run to stage : Raw TNR
7. Output : Simulate Data(Select for fine-tune usage)
8. Run



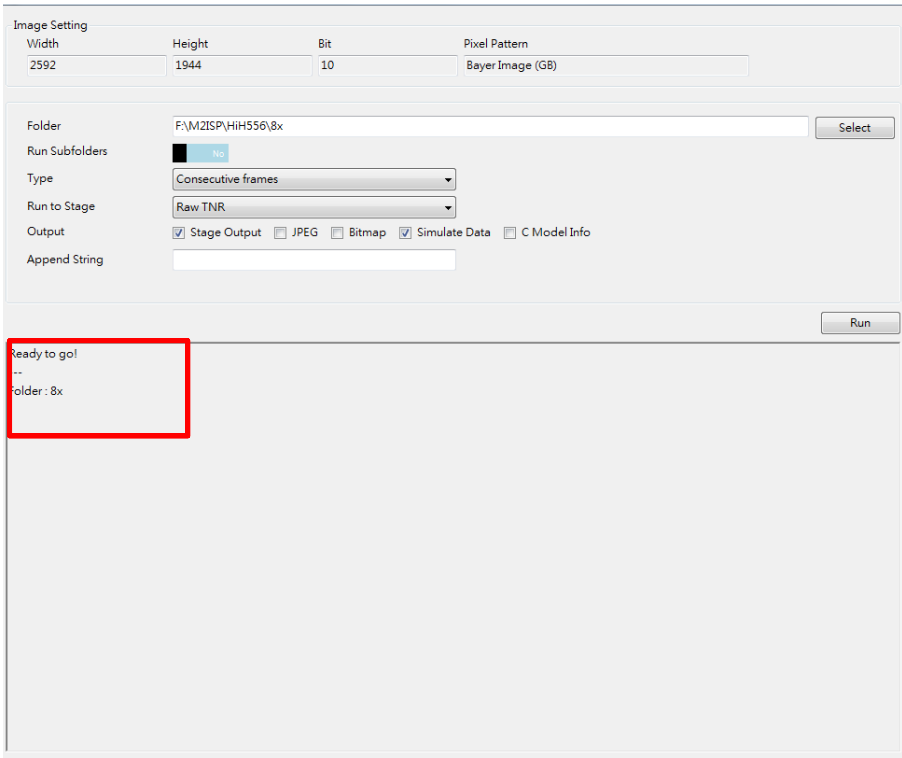
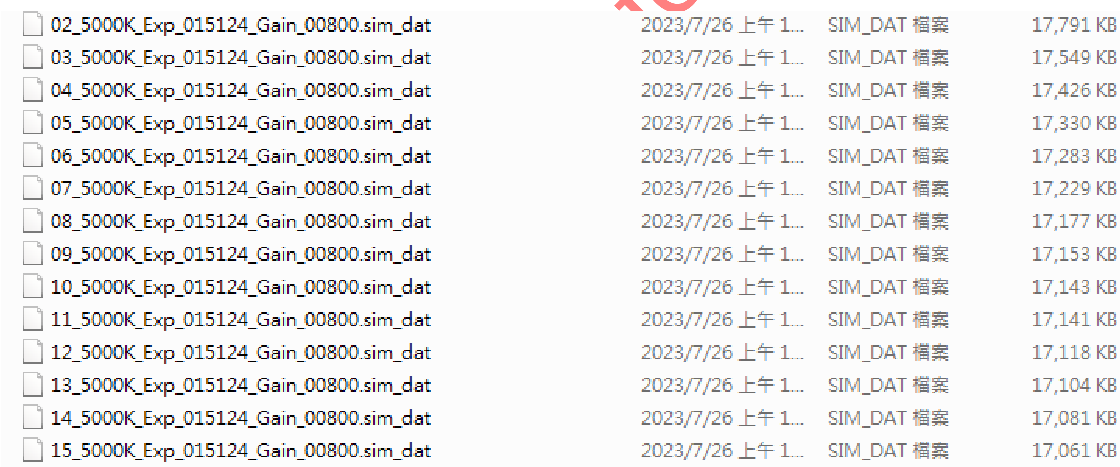


Fig. 5-24 Batch run step



02_5000K_Exp_015124_Gain_00800.sim_dat	2023/7/26 上午 1...	SIM_DAT 檔案	17,791 KB
03_5000K_Exp_015124_Gain_00800.sim_dat	2023/7/26 上午 1...	SIM_DAT 檔案	17,549 KB
04_5000K_Exp_015124_Gain_00800.sim_dat	2023/7/26 上午 1...	SIM_DAT 檔案	17,426 KB
05_5000K_Exp_015124_Gain_00800.sim_dat	2023/7/26 上午 1...	SIM_DAT 檔案	17,330 KB
06_5000K_Exp_015124_Gain_00800.sim_dat	2023/7/26 上午 1...	SIM_DAT 檔案	17,283 KB
07_5000K_Exp_015124_Gain_00800.sim_dat	2023/7/26 上午 1...	SIM_DAT 檔案	17,229 KB
08_5000K_Exp_015124_Gain_00800.sim_dat	2023/7/26 上午 1...	SIM_DAT 檔案	17,177 KB
09_5000K_Exp_015124_Gain_00800.sim_dat	2023/7/26 上午 1...	SIM_DAT 檔案	17,153 KB
10_5000K_Exp_015124_Gain_00800.sim_dat	2023/7/26 上午 1...	SIM_DAT 檔案	17,143 KB
11_5000K_Exp_015124_Gain_00800.sim_dat	2023/7/26 上午 1...	SIM_DAT 檔案	17,141 KB
12_5000K_Exp_015124_Gain_00800.sim_dat	2023/7/26 上午 1...	SIM_DAT 檔案	17,118 KB
13_5000K_Exp_015124_Gain_00800.sim_dat	2023/7/26 上午 1...	SIM_DAT 檔案	17,104 KB
14_5000K_Exp_015124_Gain_00800.sim_dat	2023/7/26 上午 1...	SIM_DAT 檔案	17,081 KB
15_5000K_Exp_015124_Gain_00800.sim_dat	2023/7/26 上午 1...	SIM_DAT 檔案	17,061 KB

Fig. 5-25 Generate TNR sim_data sequence

Use simulate Data for further fine-tune

1. Select ISP setting
2. Simulate Data (Dump from Batch Run step)
3. Load *.sim_data format for fine-tune

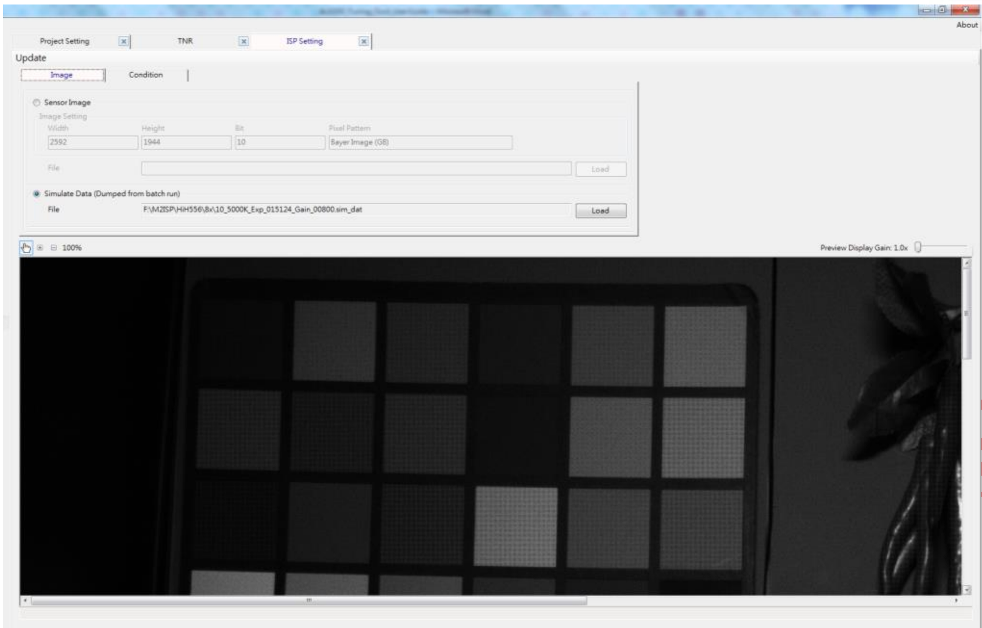


Fig. 5-26 Load TNR simulate data for fine-tune

Debug information

1. Normal simulation
2. Image after running simple IRP
3. Spatial filter
4. Confidence map
5. Temporal filter
6. Local Refine

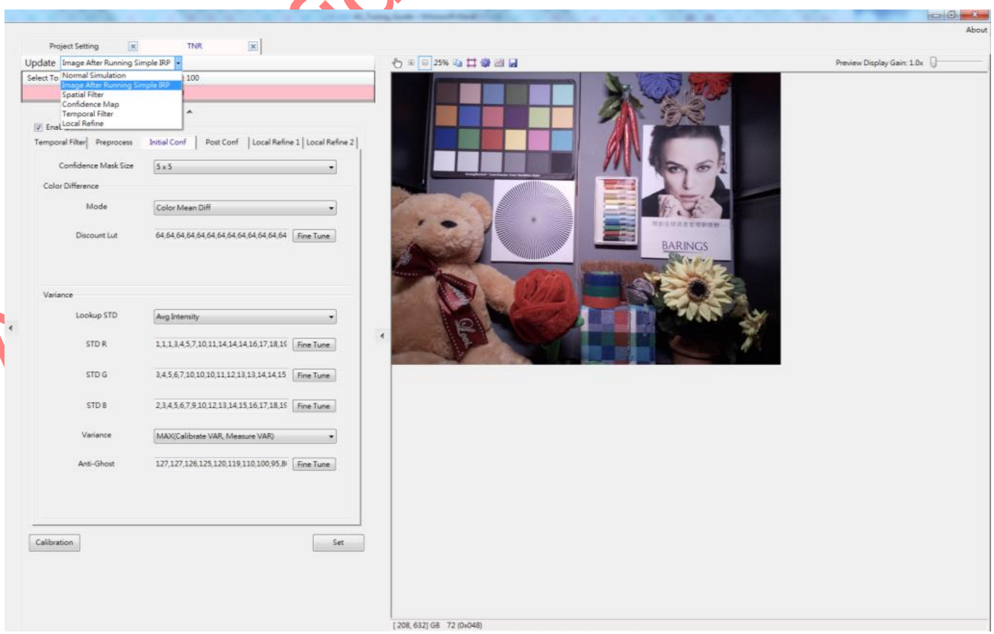


Fig. 5-27 TNR debug information

5.4. TNR Bayer Codec

Image compression is used to reduce data size for saving cost when image is stored to memory space, and Bayer Codec is a lossy compression by discarding less important information on Bayer domain. Fig. 5-28 shows that Bayer Codec is used on the TNR result in GXR1, and it is composed of TNR Bayer Codec and TNR SW Codec. TNR Bayer Codec is the kernel of Bayer Codec, and TNR SW Codec will be introduced in Chapter 5.5.

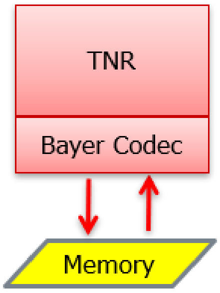
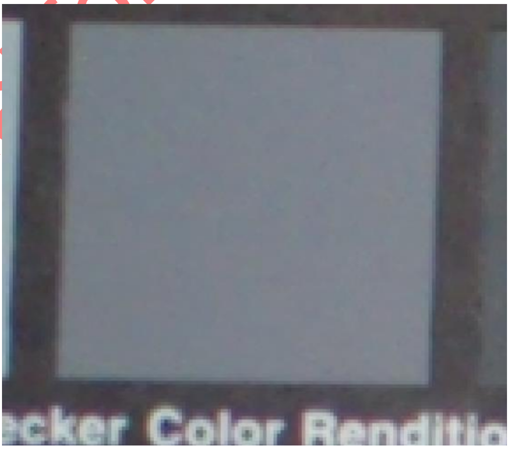


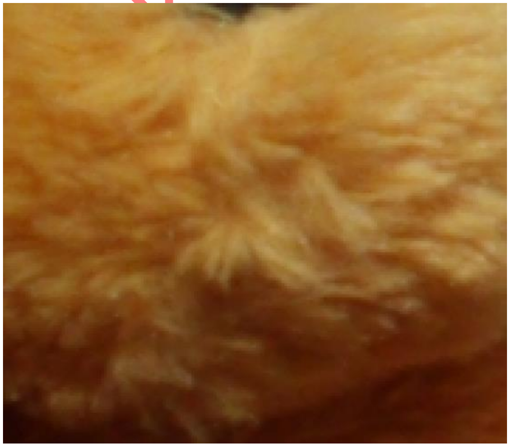
Fig. 5-28 TNR Bayer Codec in GXR1

Since Bayer Codec is lossy compression, minor detail loss or noise variation as below is acceptable, Fig. 5-29 shows the comparison between the image before and after Bayer Codec.

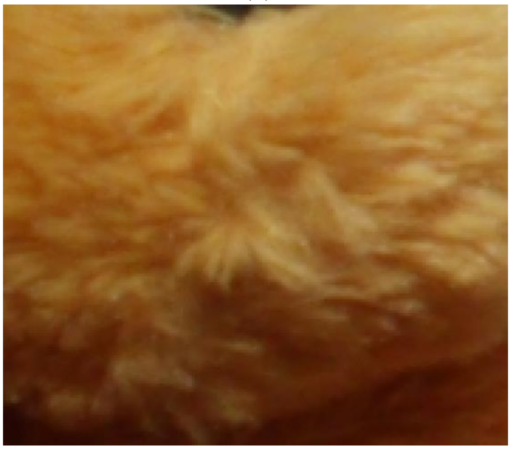
(a)



(b)



(c)



(d)

Fig. 5-29 The images before and after Bayer Codec, (a) and (c) are the images before Bayer Codec, (b) and (d) are the images after Bayer Codec.

5.4.1. Tool UI

Fig. 5-30 shows the UI of TNR Bayer Codec. Note that Default Q, Fq, Gamma Flag, Gamma and Inverse Gamma are tunable, the others are not recommended to modify.

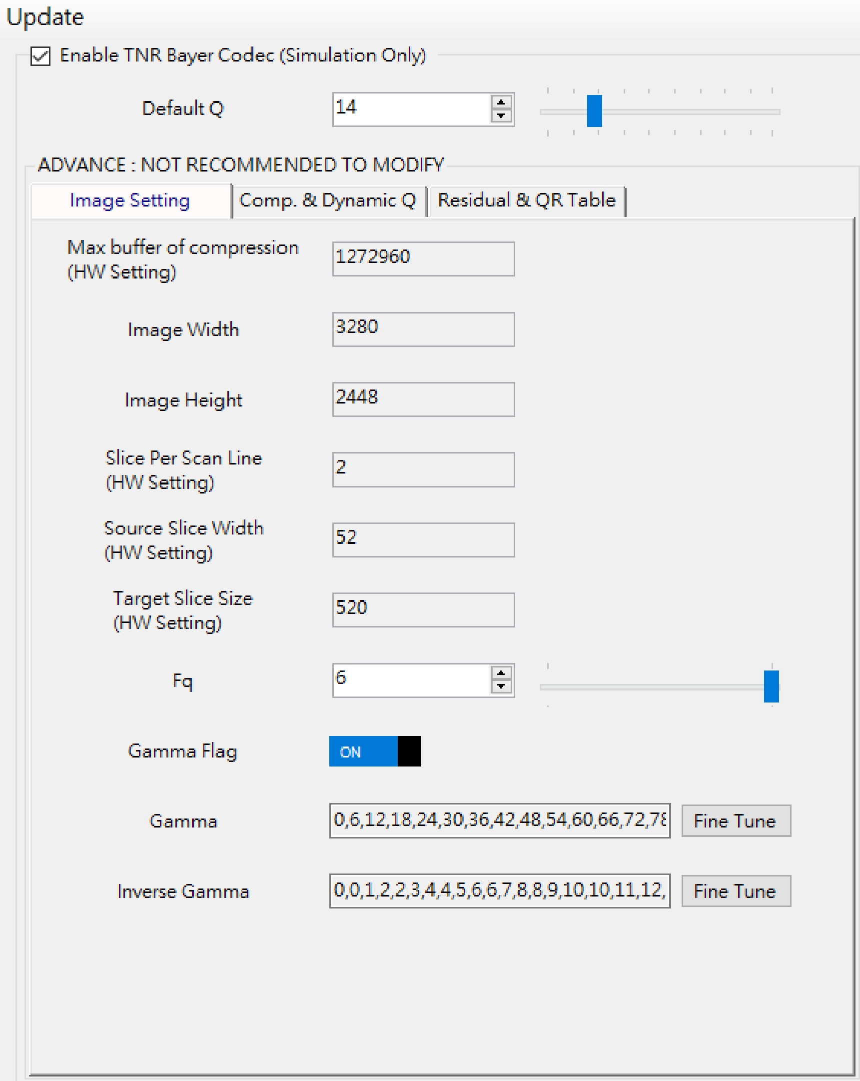


Fig. 5-30 UI of TNR Bayer Codec

5.4.2. Debug info

Fig. 5-31 shows the debug info. The debug info page will be generated after simulation, and it is used to check simulation result and the related statistics.

The debug information is as below:

- Compression: the compression simulation is success or fail.
- Ratio of Compression (%): the compression ratio of this simulation
- Q histogram: the amount of Q factors used in this simulation.

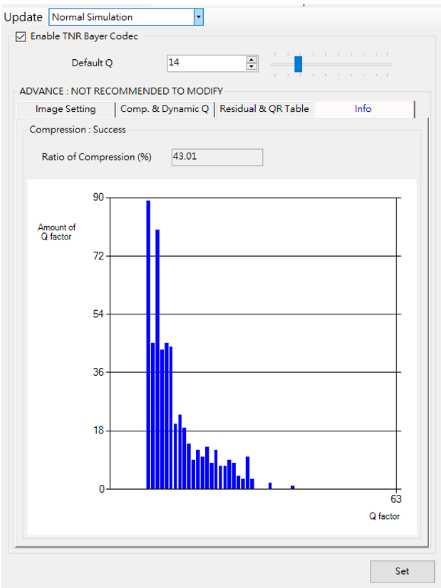
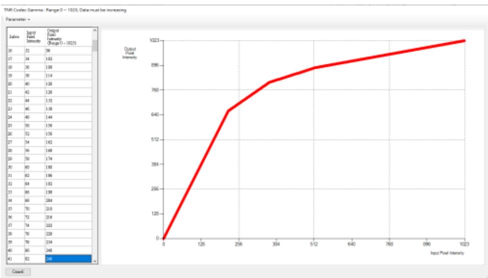


Fig. 5-31 Debug info page, it will be generated after simulation

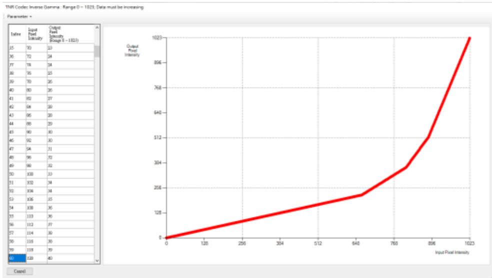
5.4.3. Tuning

Q factor is the main factor that affects compression ratio and quality, and the Q factor will be adjusted adaptively. The larger the Q factor, the smaller the compression ratio and more data loss; on the contrary, the smaller the Q factor, the bigger the compression ratio and less data loss.

- Fq
  - Fractional bit number for compression.
  - Range: 5 and 6
  - Set Fq to 6 can get smaller compression ratio, but more data loss.
  - Set Fq to 5 can make less data loss, but cause bigger compression ratio.
  - Default value is 6.
- Gamma Flag
  - Switch for Gamma and Inverse Gamma
  - Range: On and Off
  - It is recommended to set On.
- Gamma and Inverse Gamma
  - Brighten extreme dark area to prevent from excessive data loss, Fig. 5-32 shows the 2 tables in tuning tool.
  - Range: [0, 1023]
  - X-axis: input 10 bits pixel intensity.
  - Y-axis: output 10 bits pixel intensity.
  - It is recommended to use default value.



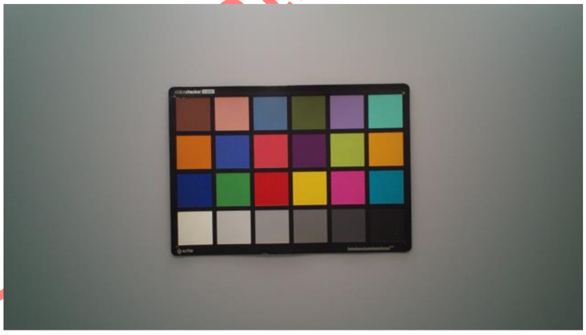
(a) Gamma



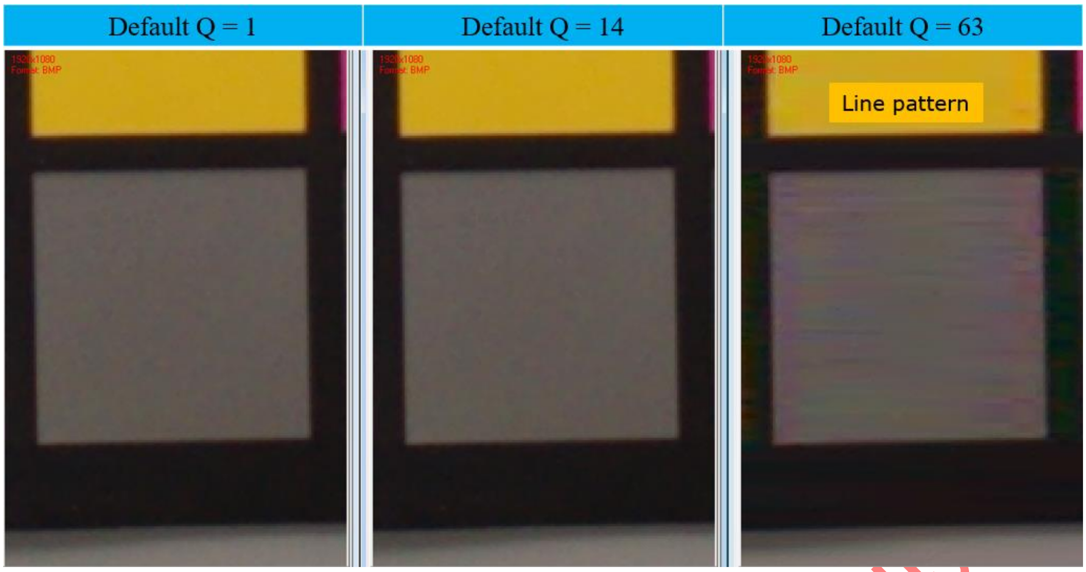
(b) Inverse Gamma

Fig. 5-32 Gamma and Inverse Gamma

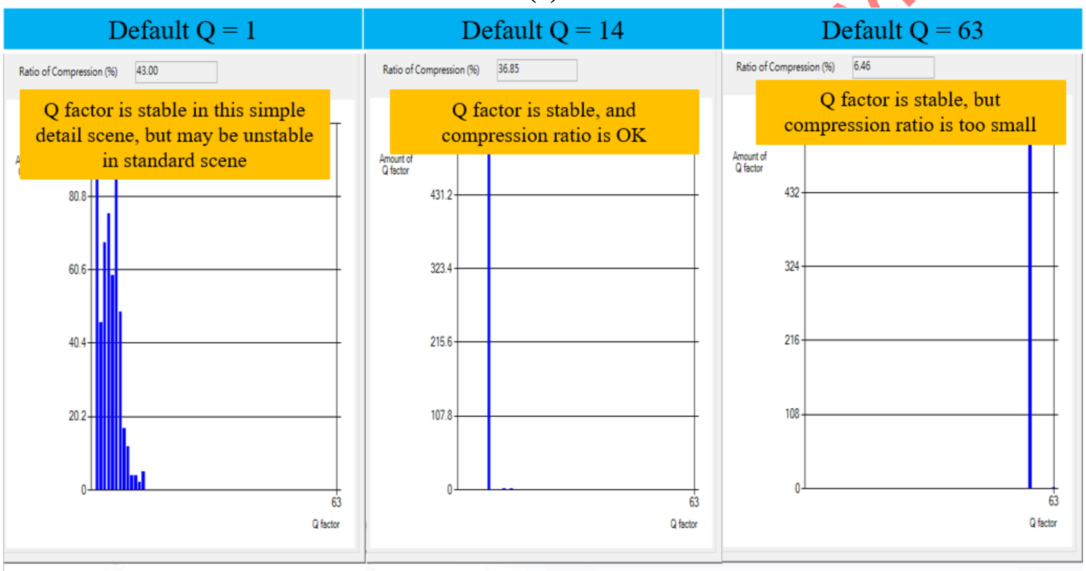
- Default Q
  - The initial value of the Q factor, then Q factor will be adjusted adaptively.
  - Range: [0~63]
  - It is used for different scenes, it should not be set to too small or too big.
  - The larger the Default Q, the smaller the compression ratio and more data loss; on the contrary, the smaller the Default Q, the bigger the compression ratio and less data loss.
  - In low texture scene such as color chart scene, usually compression ratio should be over 30%. Fig. 5-33 shows a color chart scene example by different Default Q,
  - In high texture scene such as standard scene, usually compression ratio should be over 40%. Fig. 5-34 shows a standard scene example by different Default Q.
  - Default Q in high gain scene is usually bigger than in low gain scene.



(a)

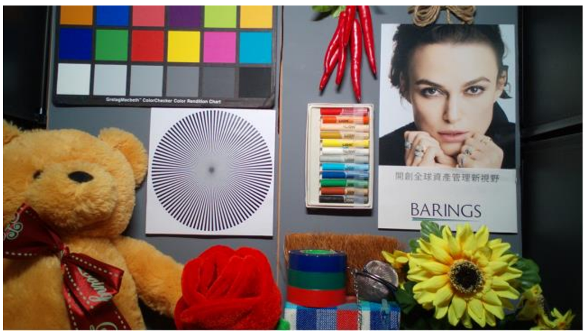


(b)



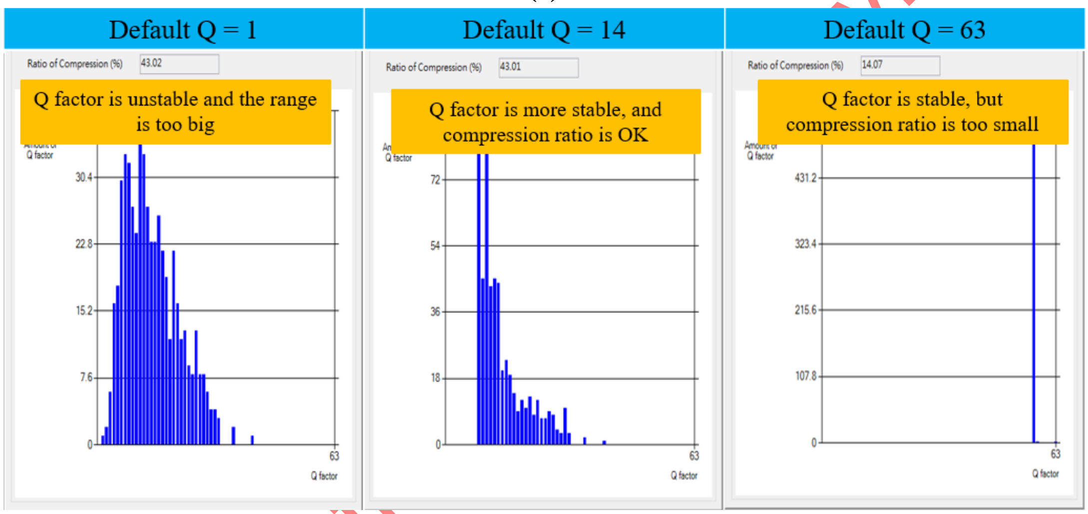
(c)

Fig. 5-33 Set different Default Q in color chart scene. (a) is an example of uniform scene; (b) and (c) shows different Bayer Codec result and debug info by setting different Default Q.



(a)

(b)



(c)

Fig. 5-34 Set different Default Q in standard scene. (a) is an example of complicated texture scene; (b) and (c) show different Bayer Codec result and debug info by different Default Q.

5.5. TNR SW Codec

TNR SW Codec is used for adaptive setting adjustment based on previous statistics.

5.5.1. Tool UI

Fig. 5-35 shows the UI of TNR SW Codec. Note that Gamma Flag in Fq 6 to 5 and in Fq 5 to 6, Gamma Flag Set, Fq Set, Gain Set and Default Q Set are tunable, the others are not recommended to modify.

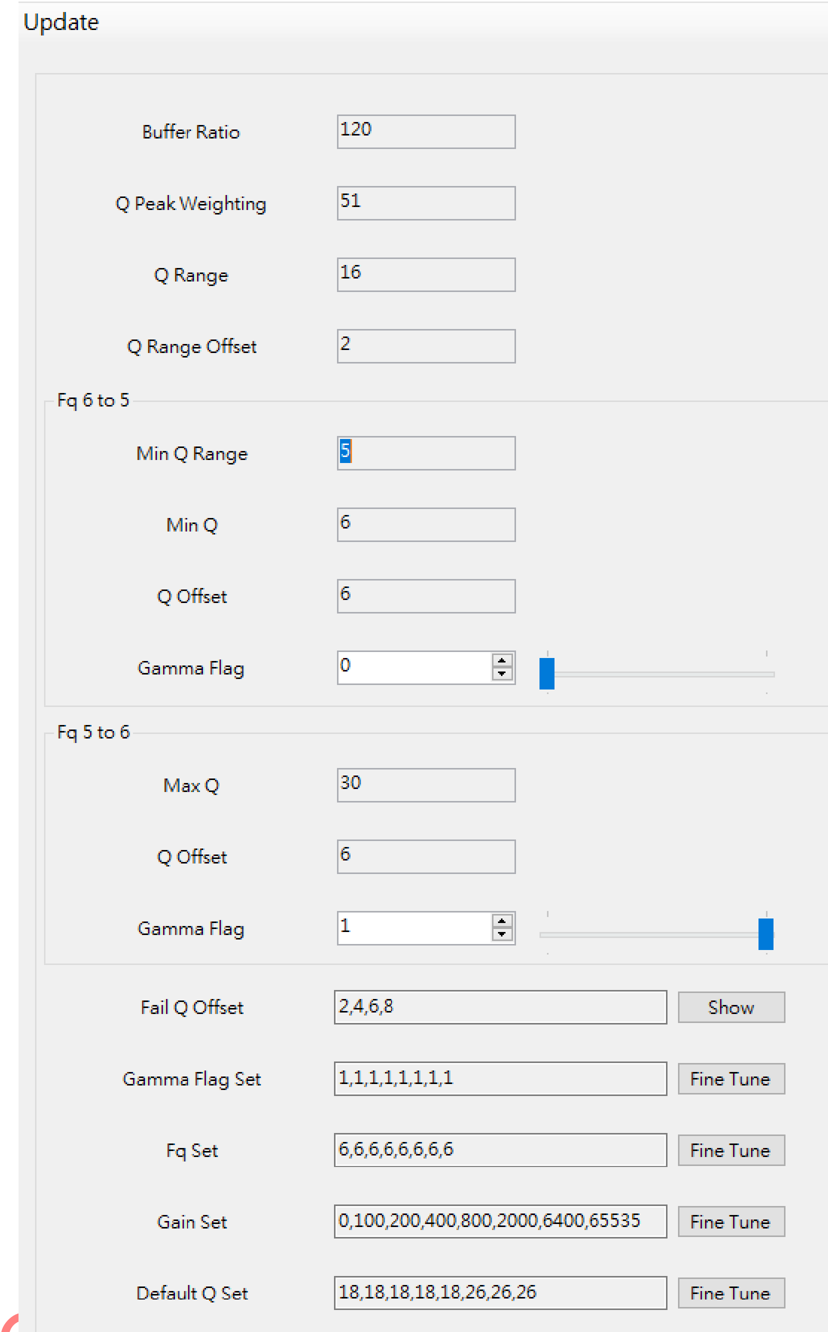


Fig. 5-35 UI of TNR SW Codec

5.5.2. Tuning Concept

Gain Set, Fq Set, Gamma Flag Set and Default Q Set are used to set Fq, Gamma Flag and Default Q according to current gain.

- Gain Set
  - ☐ Define different gain range to set different Default Q.
  - ☐ 8 elements, range: [0~65536].
  - ☐ Define gain changes if Gain Set[n] <= current gain < Gain Set[n+1], but next gain < Gain Set[n] or next gain >= Gain Set[n+1]
- Fq Set

- ☐ Set different Fq when gain changes.
- ☐ 8 elements, range: 5 and 6
- ☐ If Gain Set[n] <= next gain < Gain Set[n+1], choose Fq Set[n]
- ☐ It is recommended to set the same value for all gains.

■ Gamma Flag Set

- ☐ Set different Gamma Flag when gain changes.
- ☐ 8 elements, range: 0 and 1; 0 for Off and 1 for On
- ☐ If Gain Set[n] <= next gain < Gain Set[n+1], choose Gamma Flag Set[n]
- ☐ It is recommended to set the same value for all gains.

■ Default Q Set

- ☐ Set different Default Q when gain changes.
- ☐ 8 elements, range: [0~63].
- ☐ If Gain Set[n] <= next gain < Gain Set[n+1], choose Default Q Set[n]

■ Example

- ☐ Assume Gain Set = {0, 100, 200, 400, 800, 2000,3200, 65535}, Default Q Set = {14, 14, 14, 14, 14, 26, 26, 26}, current gain = 1600, next gain = 2200.
- ☐ Gain Set[4] = 800 <= 1600 < Gain Set[5] = 2000, but next gain = 2200 > Gain Set[5], then gain changes.
- ☐ Since Gain Set[5] = 2000 <= 2200 < Gain Set[6] = 3200, set Default Q = Default Q Set[5] = 26.

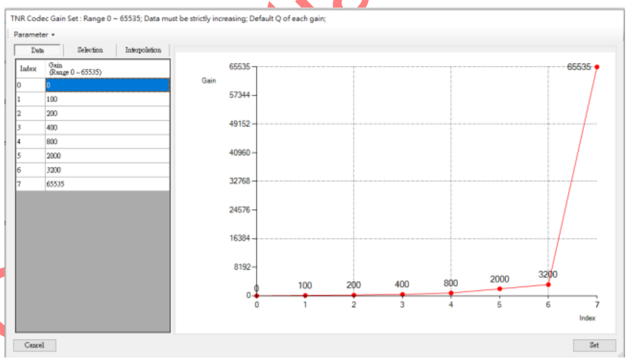


Fig. 5-36 Gain Set

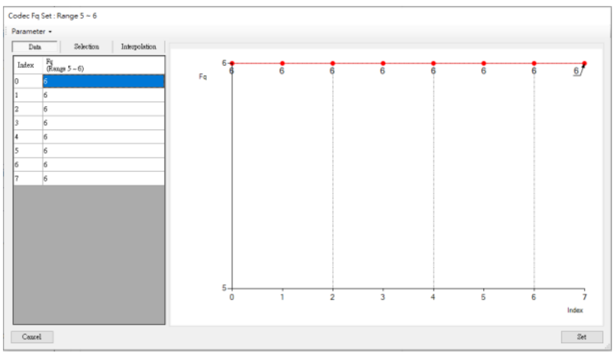


Fig. 5.37 Fq Set

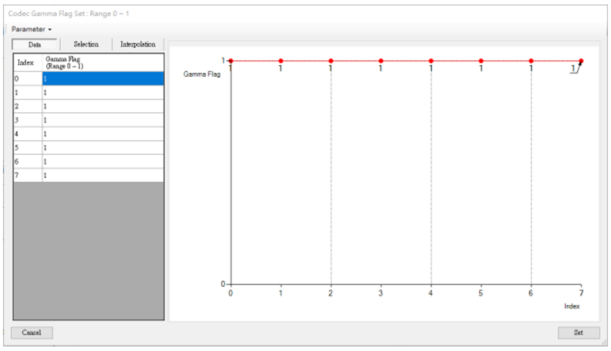


Fig. 5.38 Gamma Flag Set

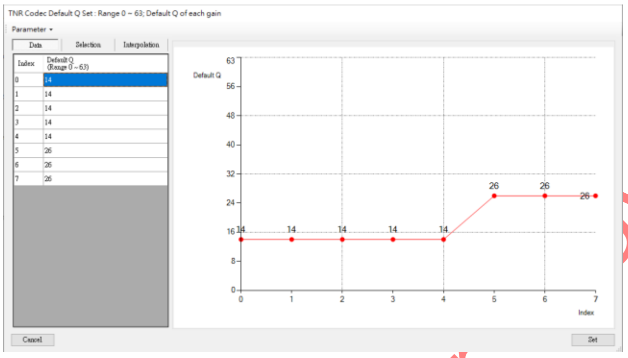


Fig. 5-39 Default Q Set

- Gamma Flag for Fq 6 to 5
  - ☐ When Fq is 6, and the Default Q is too small and stable, but the compression ratio is still too small, SW Codec will consider to set Fq to 5 for increase compression ratio.
  - ☐ It is recommended to set to 0.
- Gamma Flag for Fq 5 to 6
  - ☐ When Fq is 5, and the Default Q is too big, SW Codec will consider to set Fq to 6.
  - ☐ It is recommended to set to 1.

5.5.3. Calibration flow

1. Confirm the image resolution to check if Bayer Codec needs to enable.
2. Prepare 1 low texture scene such as color chart scene and 1 high texture scene such as standard scene for different gains. See example in Fig. 5-40 for two kind of scenes.

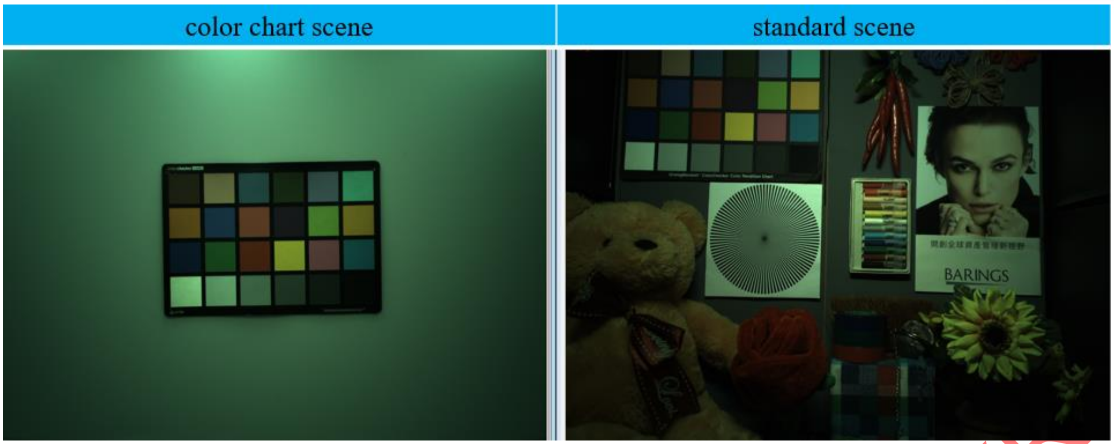


Fig. 5-40 Example of two kind of scenes.

3. Color temperature: 5000K.
4. Usual gain: 1x、4x、8x、16x、24x and 32x gain.
5. Set Fq to 6 for all gains.
6. Set Default Q for different gains:
   (a) Find a default Q to make the variation of Q factor be stable and without artifact, and compression ratio is not too small for both scenes.
   (b) Default Q is used for different scenes, it should not be too small or too big.
   (c) Usually compression ratio should be over 30% in color chart scene, and be over 40% in standard scene.
   (d) Default Q for high gain is usually bigger than Default Q for low gain.
7. All suitable default Q for different gains will be set to Gain Set and Default Q Set, then set Gamma Flag, Fq and Default Q in Bayer Codec to Gamma Flag Set[0], Fq Set[0] and Default Q Set[0], separately.

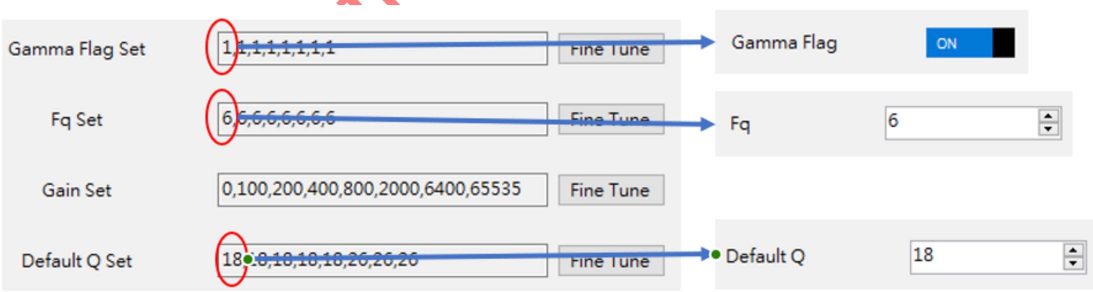
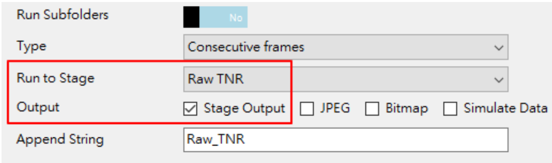


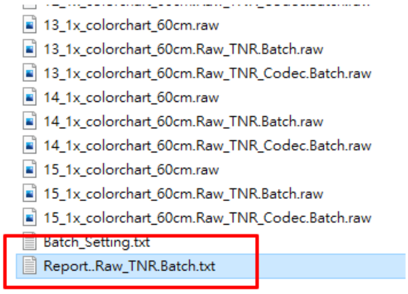
Fig. 5-41 Default Q and Default Q Set

5.5.4. Batch Run

Batch run simulation will generate sequential images by TNR and Bayer Codec. In batch run setting, set Run to Stage to Raw TNR, and tick the checkbox Stage Output as Fig. 5-42, it will generate all Bayer Codec results and report data.



(a)



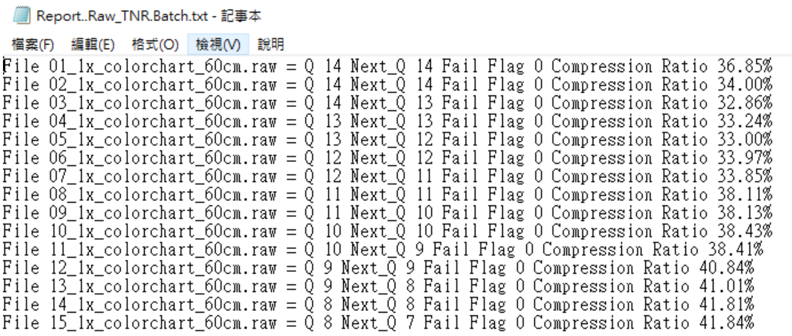
(b)

Fig. 5-42 (a) shows the batch run setting to generate Bayer Codec result and report data; (b) shows the report data name Report_Raw_TNR.Bacth.txt

The below is the format of report data, see the example in Fig. 5-43:

File Filename = Q value1 Next_Q value2 Fail Flag value3 Compression Ratio value4

- File Filename: the source image name
- Q value1: value1 is the Default Q of current frame
- Next_Q value2: value2 is the Default Q for next frame which is predicted by TNR SW Codec
- Fail Flag value3: value3 is 1 that means compression fail and is 0 that means compression success
- Compression Ratio value4: the compression ratio of current frame


Report..Raw_TNR.Batch.txt - 記事本
檔案(F) 編輯(E) 格式(O) 檢視(V) 說明

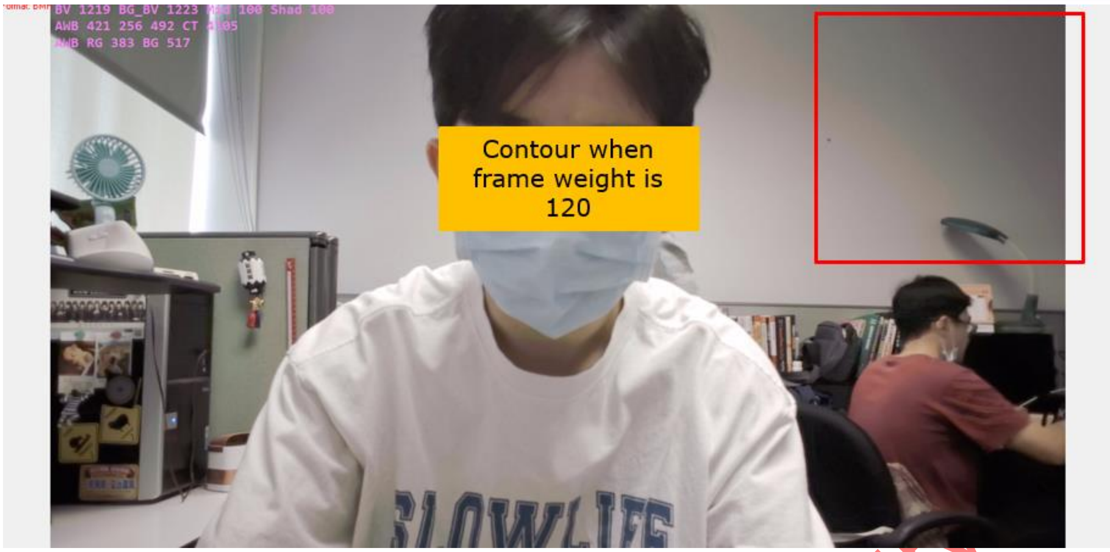
```
File 01_1x_colorchart_60cm.raw = Q 14 Next_Q 14 Fail Flag 0 Compression Ratio 36.85%
File 02_1x_colorchart_60cm.raw = Q 14 Next_Q 14 Fail Flag 0 Compression Ratio 34.00%
File 03_1x_colorchart_60cm.raw = Q 14 Next_Q 13 Fail Flag 0 Compression Ratio 32.86%
File 04_1x_colorchart_60cm.raw = Q 13 Next_Q 13 Fail Flag 0 Compression Ratio 33.24%
File 05_1x_colorchart_60cm.raw = Q 13 Next_Q 12 Fail Flag 0 Compression Ratio 33.00%
File 06_1x_colorchart_60cm.raw = Q 12 Next_Q 12 Fail Flag 0 Compression Ratio 33.97%
File 07_1x_colorchart_60cm.raw = Q 12 Next_Q 11 Fail Flag 0 Compression Ratio 33.85%
File 08_1x_colorchart_60cm.raw = Q 11 Next_Q 11 Fail Flag 0 Compression Ratio 38.11%
File 09_1x_colorchart_60cm.raw = Q 11 Next_Q 10 Fail Flag 0 Compression Ratio 38.13%
File 10_1x_colorchart_60cm.raw = Q 10 Next_Q 10 Fail Flag 0 Compression Ratio 38.43%
File 11_1x_colorchart_60cm.raw = Q 10 Next_Q 9 Fail Flag 0 Compression Ratio 38.41%
File 12_1x_colorchart_60cm.raw = Q 9 Next_Q 9 Fail Flag 0 Compression Ratio 40.84%
File 13_1x_colorchart_60cm.raw = Q 9 Next_Q 8 Fail Flag 0 Compression Ratio 41.01%
File 14_1x_colorchart_60cm.raw = Q 8 Next_Q 8 Fail Flag 0 Compression Ratio 41.81%
File 15_1x_colorchart_60cm.raw = Q 8 Next_Q 7 Fail Flag 0 Compression Ratio 41.84%
```

Fig. 5-43 example of report data

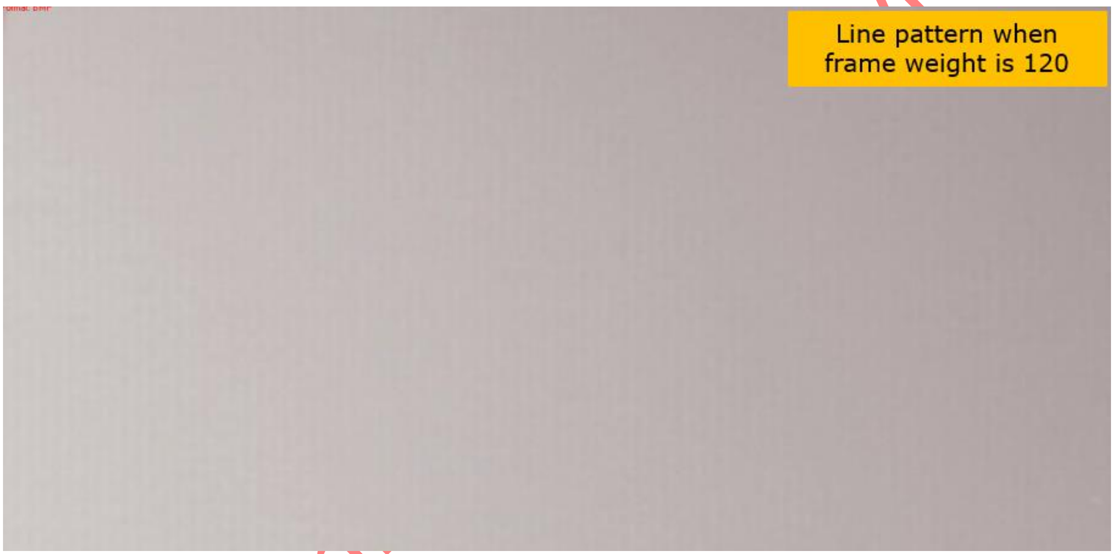
5.5.5. Liveview

In liveview or video, compression failure may happen. It often caused by rapid and drastic scene change like unstable AE, unstable Face Detection, unstable Human Detection or global motion scene. When it happens, TNR would bypass temporal filter and the temporal noise will be bigger until compression success. Usually compression failure seldom happens in global motion scene is acceptable, and it should not happen in stable scene. Hence AE, Face Detection and Human Detection are needed to be stable.

Note that TNR Frame Weight is set to too big may cause contour or line pattern. Usually it is not recommended to set to over 110. See the side effect example in Fig. 5-44.



(a)



(b)

Fig. 5-44 Side effect when TNR Frame Weight is 120; (a) shows contour in the corner of the image; (b) shows the line pattern in flat area.

Note that the above side effect also may occur when compression ratio is too small or too much data loss. Please check the compression ratio of all frames by batch run, and try to decrease Default Q. If it still happens even Default Q is set to close to 0, set Gamma Flag to 0 or set Fq to 5 is another way for reducing data loss. But note that Default Q should also be finetuned when Gamma Flag or Fq changes.

5.6. SNR

- Spatial Noise Reduction (SNR) is a denoise technique in Bayer domain.
- Raw denoise kernel accepts only 10-bits raw image after TNR (Temporal Noise Reduction), the output is also 10-bits raw image.
- Tuning Order:
    - Local Denoise → Edge Filter → Pixel Compensation

- Local Denoise
  - Tune the denoise level for R、Gr、Gb、B channels.
  - Tune the denoise level for each pixel intensity zone.
- Edge Filter
  - Define the edge threshold to classify the edge direction.
  - Tune the denoise level for each edge direction.
- Pixel Compensation
  - Resume the signal for smooth or texture area.
  - Resume the signal for each pixel intensity zone.

5.6.1. Local Denoise

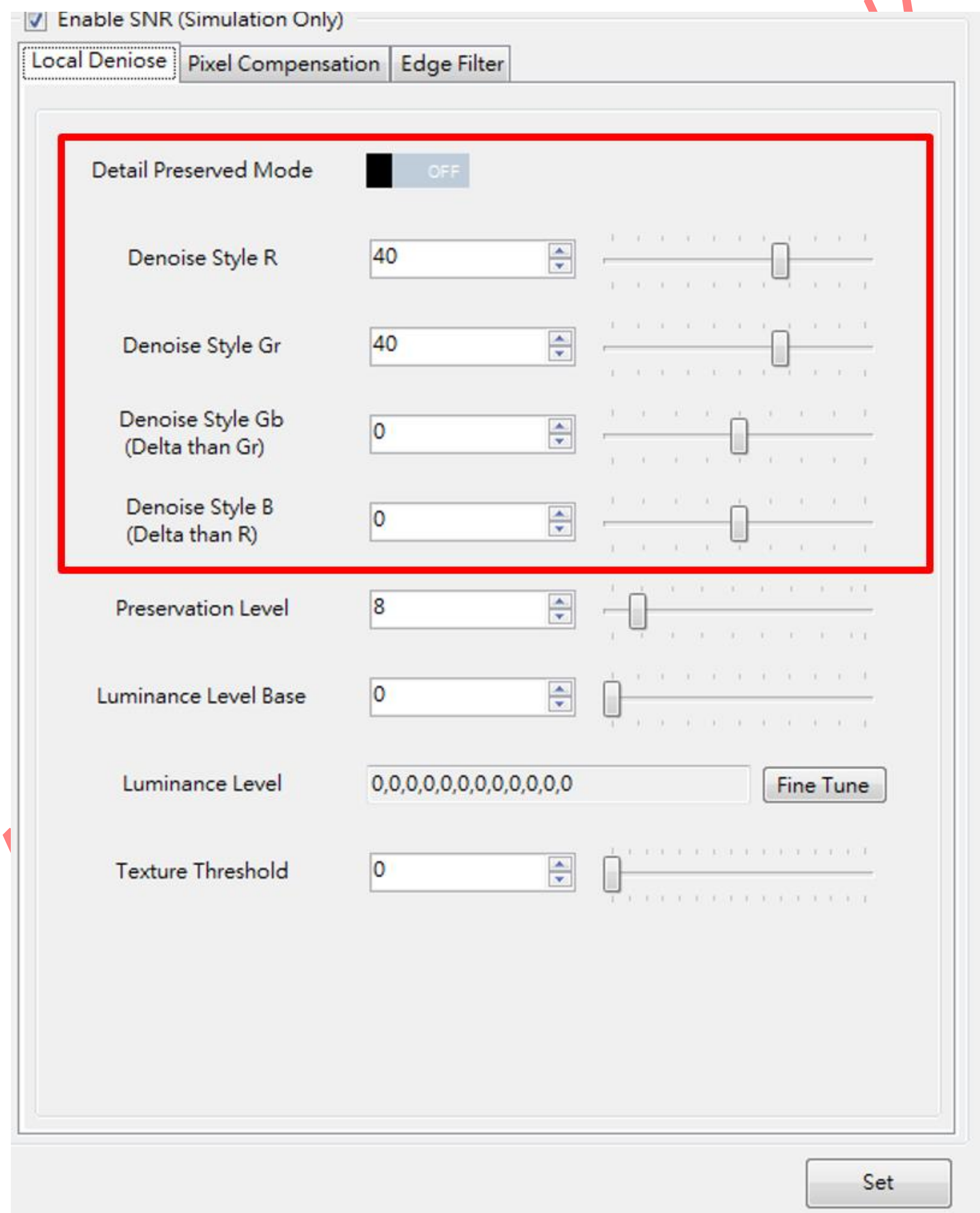


Fig. 5-45 Local Denoise UI

- Detail Preserved Mode
  - On: preserve cluster detail.
  - Off: smooth cluster detail.
- Denoise Style R/Gr
  - Denoise level, increase this level, more noise reduction.
  - Default = 30
  - Range:0~60
- Denoise Style Gb/B
  - The offset to the Denoise Style R/Gr
  - increase this offset, more noise reduction than R/Gr channels.
  - Default = 0
  - Range: -24~24

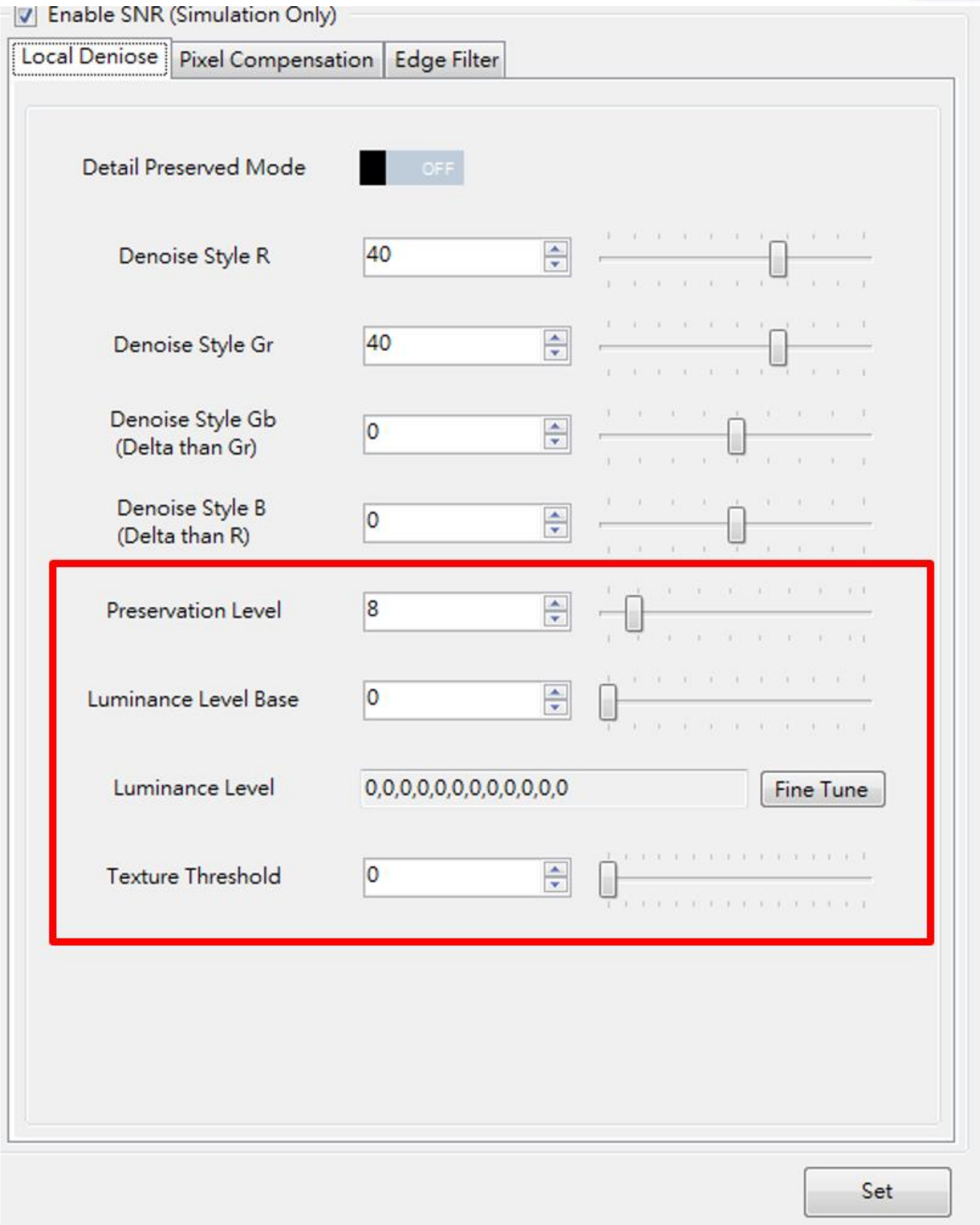


Fig. 5-46 Local Denoise UI

- Preservation Level
  - Preserve detail level
  - decrease this value, keep more detail.
  - Increase this value, more noise reduction.
  - Range:0~76, default = 7
- Luminance Level Base
  - The base of denoise level to all luminance.
  - Increase this value, more noise reduction.
  - Range:0~10, default = 0
- Luminance Level
  - The denoise level to each luminance zone.

- Increase this value, more noise reduction.
- Range:0~15, default = 0

■ Texture Threshold

- Increase this threshold, more pixels are classified into smooth regions.
- Range:0~65535

5.6.2. Edge Filter

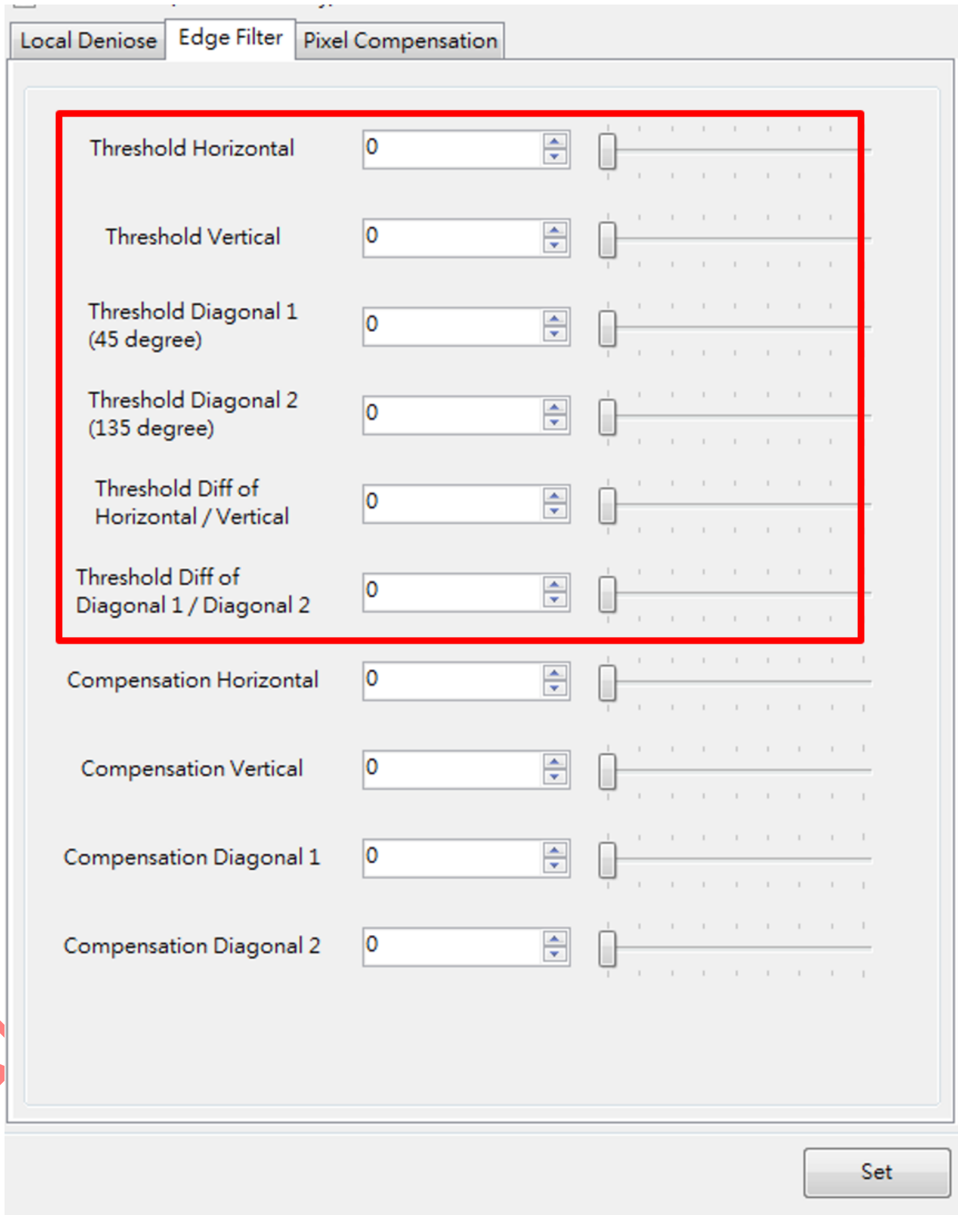


Fig. 5-47 Edge Filter UI

■ The threshold to classify the edge direction

- Threshold Horizontal
  - Increase this threshold, more pixels are classified into horizontal direction.
  - Range:0~2047, default = 0

- Threshold Vertical
  - Increase this threshold, more pixels are classified into vertical direction.
  - Range:0~2047, default = 0
- Threshold Diagonal1(45 degree)
  - Increase this threshold, more pixels are classified into 45 degree direction.
  - Range:0~2047, default = 0
- Threshold Diagonal2(135 degree)
  - Increase this threshold, more pixels are classified into 135 degree direction.
  - Range:0~2047, default = 0
- Threshold Diff of Horizontal/Vertical
  - Increase this threshold, more pixels are easily classified into smooth area.
  - Range:0~2047, default = 0
- Threshold Diff of Diagonal1/Diagonal2
  - Increase this threshold, more pixels are easily classified into smooth area.
  - Range:0~2047, default = 0

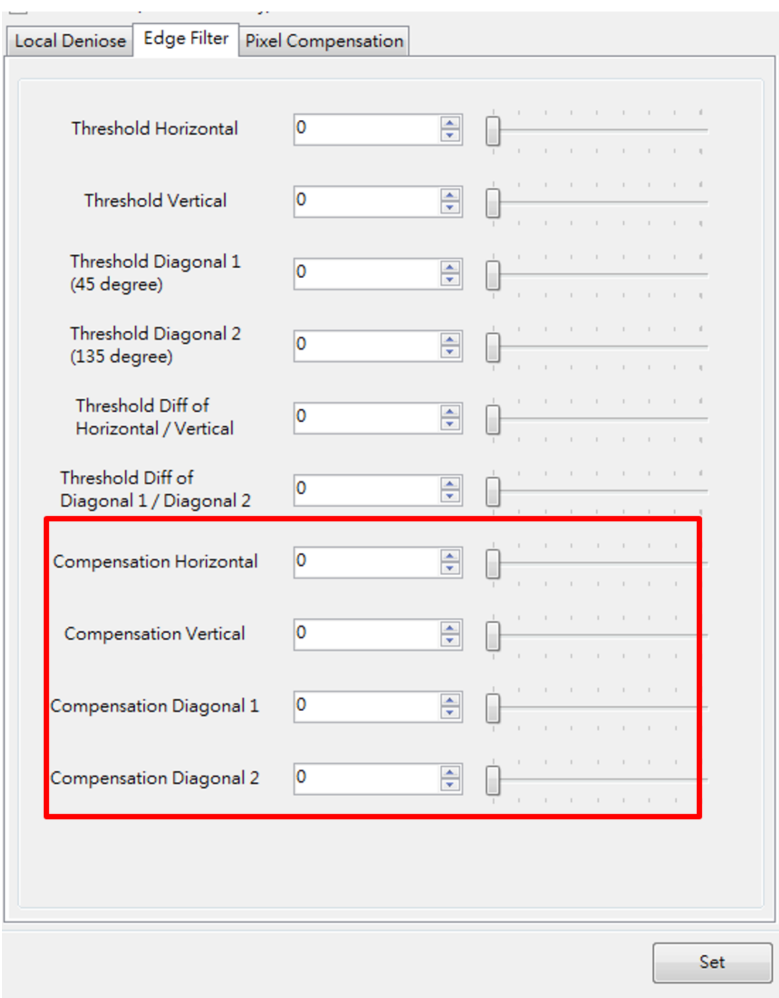


Fig. 5-48 Edge Filter UI

- The de-noise level to each edge direction
  - Compensation Horizontal
    - Increase this level, more de-noise along the horizontal edge.
    - Range:0~24, default = 0
  - Compensation Vertical
    - Increase this threshold, more de-noise along the vertical edge.
    - Range:0~24, default = 0
  - Compensation Diagonal1(45-degree)
    - Increase this threshold, more de-noise along the 45-degree edge.
    - Range:0~24, default = 0
  - Compensation Diagonal2(135-degree)
    - Increase this threshold, more de-noise along the 135-degree edge.
    - Range:0~24, default = 0

5.6.3. Pixel Compensation

Please refer to Fig. 5.48 the pixel compensation UI

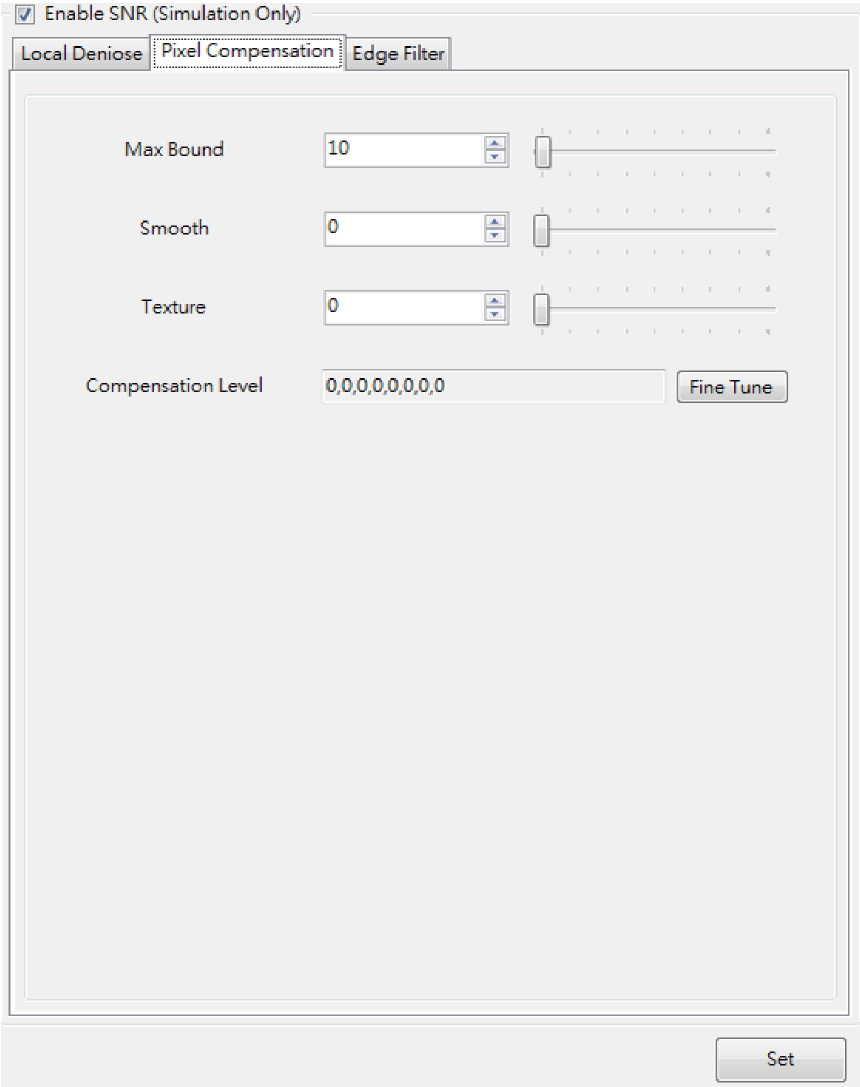


Fig. 5-49 Pixel Compensation UI

- Max Bound
  - The max limitation of resuming signal.
  - Range:0~1023, default = 10
- Smooth
  - The percentage to resume signal for smooth area.
  - Range:0~1023(100%), default = 0
- Texture
  - The percentage to resume signal for texture area.
  - Range:0~1023(100%), default = 0
- Compensation Level
  - The percentage to resume signal for each intensity zone.
  - Range:0~1023(100%), default = 0

5.7. IRP 1 CFAi

The purpose of CFAi is to convert Bayer pattern become full resolution RGB.

Bayer pattern is placed RGB color filter in one plane but different position. Here needs algorithm to interpolate missing colors and induce parameters for controlling interpolation behavior. In below show the tuning parameters and follows.

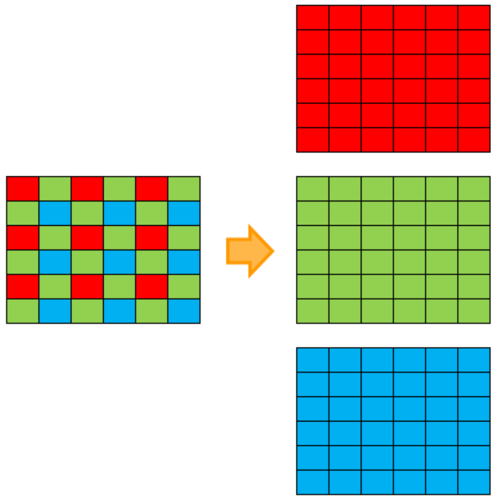


Fig. 5-50 Bayer pattern to full resolution RGB

5.7.1. Tuning follow 1

Select Blur, Normal and Sharp Mask, where 0:blur, 1:normal, 2:sharp

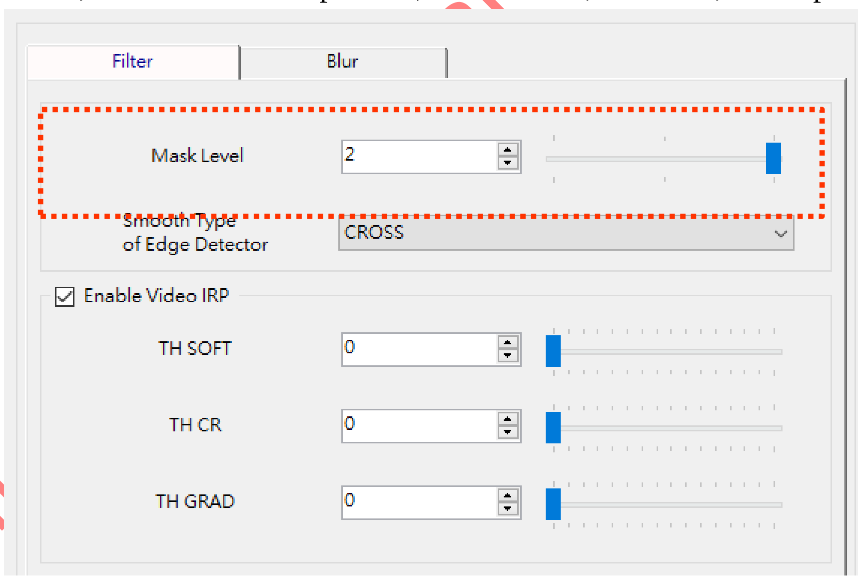


Fig. 5-51 CFAi filter

Blur Normal Sharp

Fig. 5-52 CFAi filter

A blur mask interpolates pixels by lowpass filter, and always blurring image. Normal and sharp combine unsharp masking for clearing image, however, induce overshooting at strong edge.

5.7.2. Tuning follow 2

Decide Luminance Edge threshold: Set smaller value to force stronger line connection

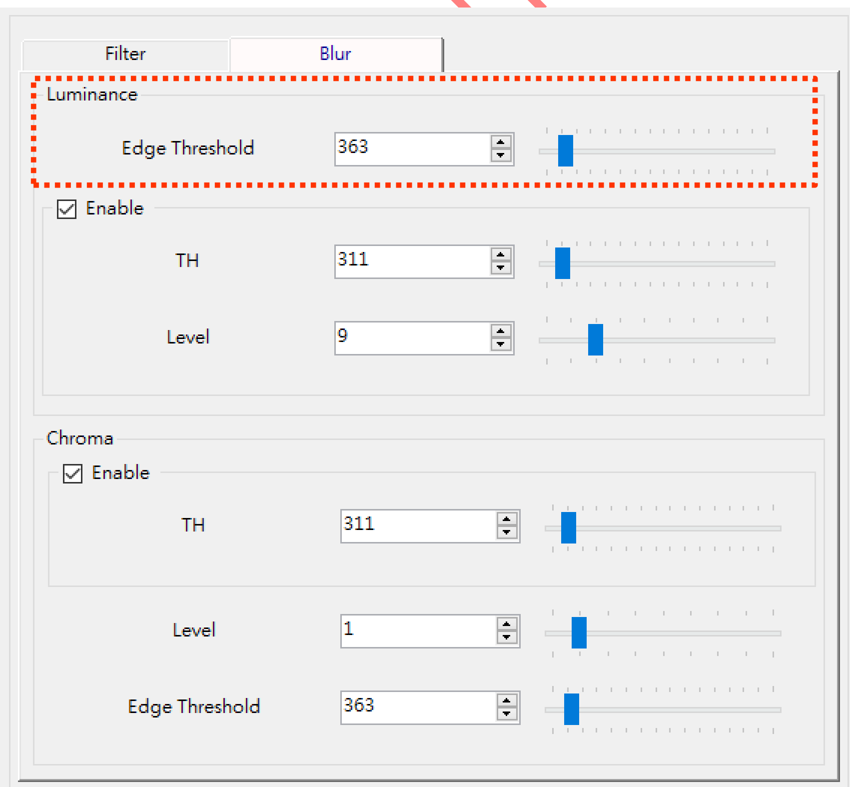


Fig. 5-53 CFAi Blur

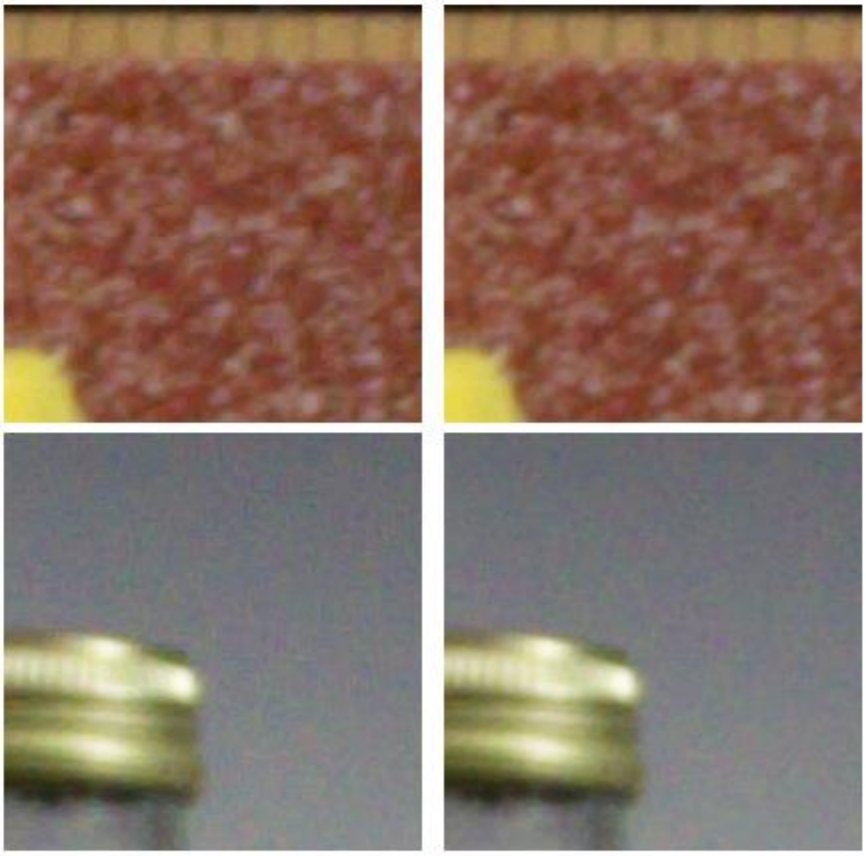


Fig. 5-54 CFAi Blur Edge Threshold

A small threshold will give an aggressive connection between pixel and pixel. It makes lines seems continuous and smoothing but also on noisy region. In general, this setting should higher than noise level.

5.7.3. Tuning follow 3

Reduce small pattern: the blurring pattern under TH

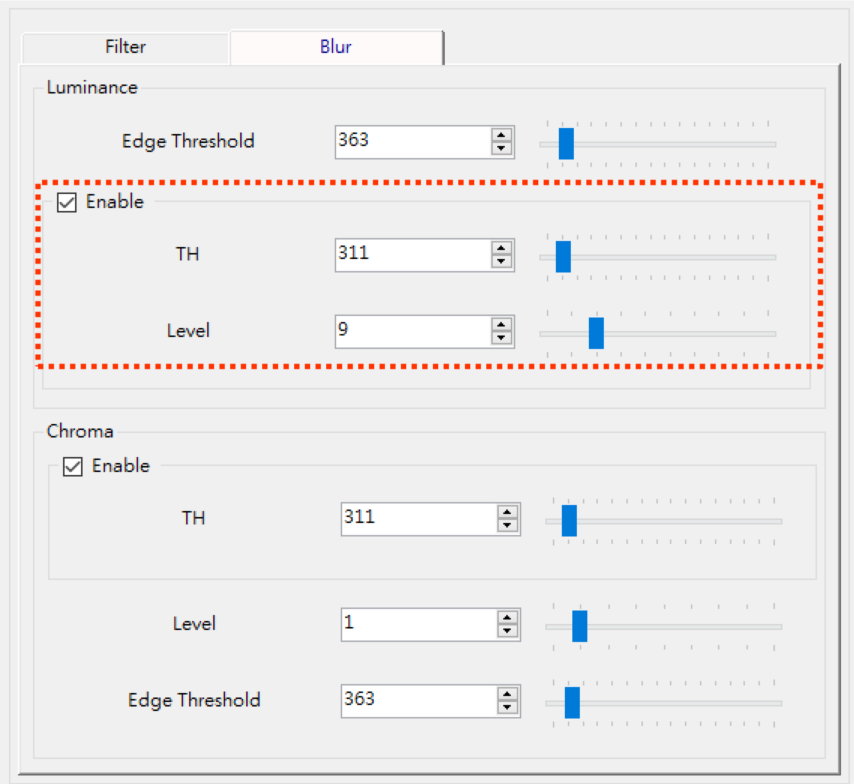


Fig. 5-55 CFAi Blur level

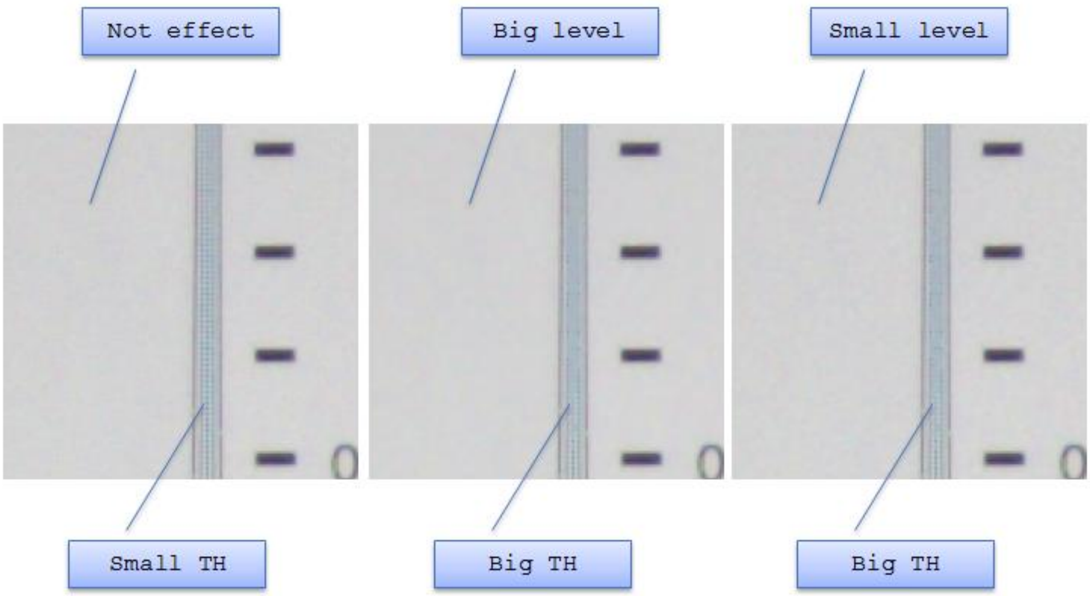


Fig. 5-56 CFAi Blur level example

If there are intensive lines in image and the line frequency is out of filter handing, the algorithm could not solve the lines correctly. In this situation, you can choose to leave pattern or to blur them. For blurring the pattern, set the TH to cover pattern region and level for blurring strength.

5.7.4. Tuning follow 4

Video IRP mode

- For solving more lines
- Choose a responsible setting for initial

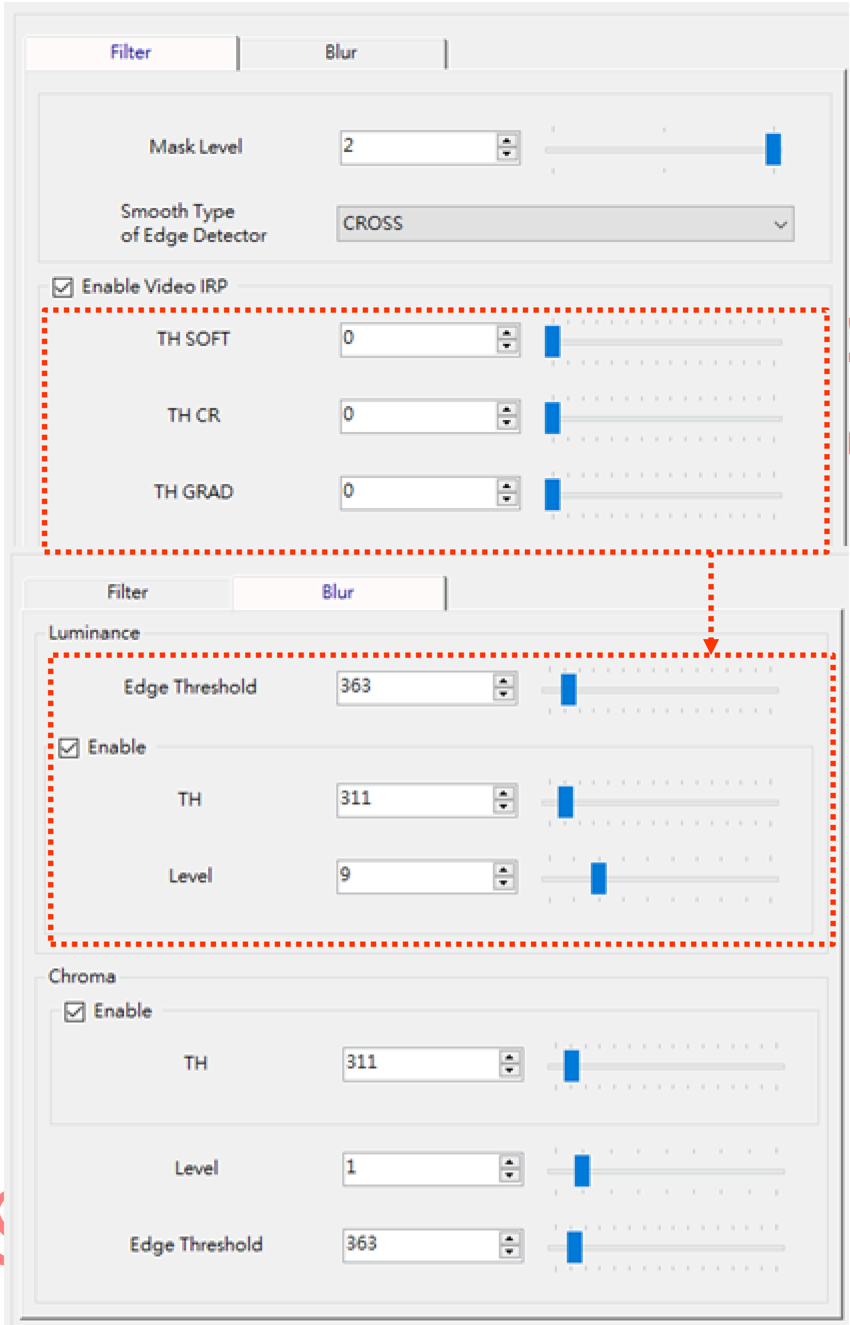


Fig. 5-57 CFAi Video IRP mode

Video IRP mode is used to save more lines when frequency is out of handing. Even can not handing but still want to take risk to resolve. Here is the option for this purpose.

However, these parameters are not certainly rules to control quality changing. Suggest to select one of setting in profles and then go adjusting. Below are profiles with different style of these 3 parameters’ combinations. These 3 parameters also relate to Luminance parameters and should to be adjusted together.

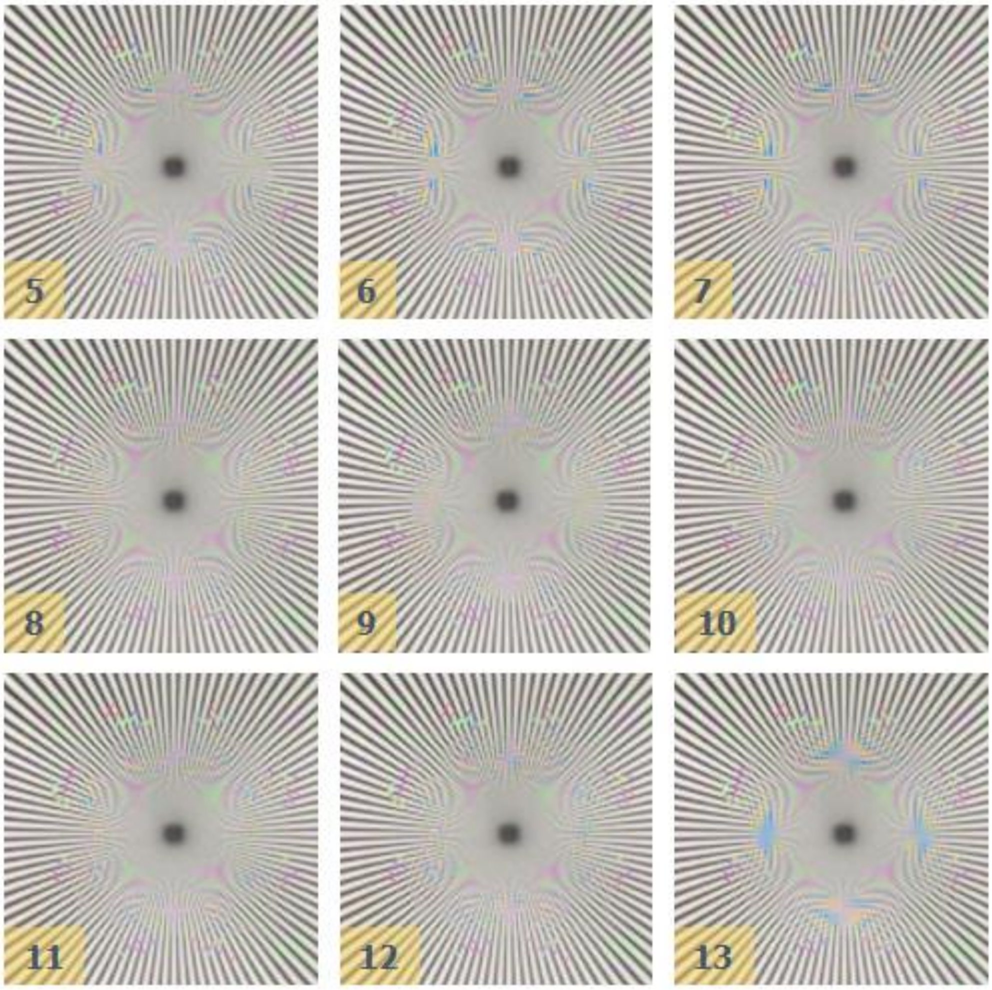


Fig. 5-58 CFAi Video IRP mode example

Responding setting as below:

[5] mask level = 2 [VideoIRP] TH SOFT = 110 [VideoIRP] TH CR = 10 [VideoIRP] TH GRAD = 360 [Luminance] Edge Threshold = 140 [Luminance] TH = 180 [Luminance] level = 10	[6] mask level = 2 [VideoIRP] TH SOFT = 55 [VideoIRP] TH CR = 10 [VideoIRP] TH GRAD = 180 [Luminance] Edge Threshold = 70 [Luminance] TH = 90 [Luminance] level = 10	[7] mask level = 2 [VideoIRP] TH SOFT = 15 [VideoIRP] TH CR = 10 [VideoIRP] TH GRAD = 220 [Luminance] Edge Threshold = 60 [Luminance] TH = 10 [Luminance] level = 12
[8] mask level = 2 [VideoIRP] TH SOFT = 85 [VideoIRP] TH CR = 20 [VideoIRP] TH GRAD = 320 [Luminance] Edge Threshold = 320 [Luminance] TH = 20 [Luminance] level = 10	[9] mask level = 2 [VideoIRP] TH SOFT = 85 [VideoIRP] TH CR = 20 [VideoIRP] TH GRAD = 320 [Luminance] Edge Threshold = 320 [Luminance] TH = 220 [Luminance] level = 10	[10] mask level = 2 [VideoIRP] TH SOFT = 285 [VideoIRP] TH CR = 20 [VideoIRP] TH GRAD = 120 [Luminance] Edge Threshold = 80 [Luminance] TH = 30 [Luminance] level = 10
[11] mask level = 2 [VideoIRP] TH SOFT = 285 [VideoIRP] TH CR = 20	[12] mask level = 2 [VideoIRP] TH SOFT = 285 [VideoIRP] TH CR = 20	[13] mask level = 2 [VideoIRP] TH SOFT = 285 [VideoIRP] TH CR = 20

[VideoIRP] TH GRAD = 320	[VideoIRP] TH GRAD = 520	[VideoIRP] TH GRAD = 320
[Luminance] Edge Threshold = 80	[Luminance] Edge Threshold = 80	[Luminance] Edge Threshold = 180
[Luminance] TH = 30	[Luminance] TH = 30	[Luminance] TH = 130
[Luminance] level = 10	[Luminance] level = 10	[Luminance] level = 10

5.7.5. Tuning follow 5

Reduce color aliasing:

- Suggest set small values for most of case.
- Depended on issue scene for special tuning.

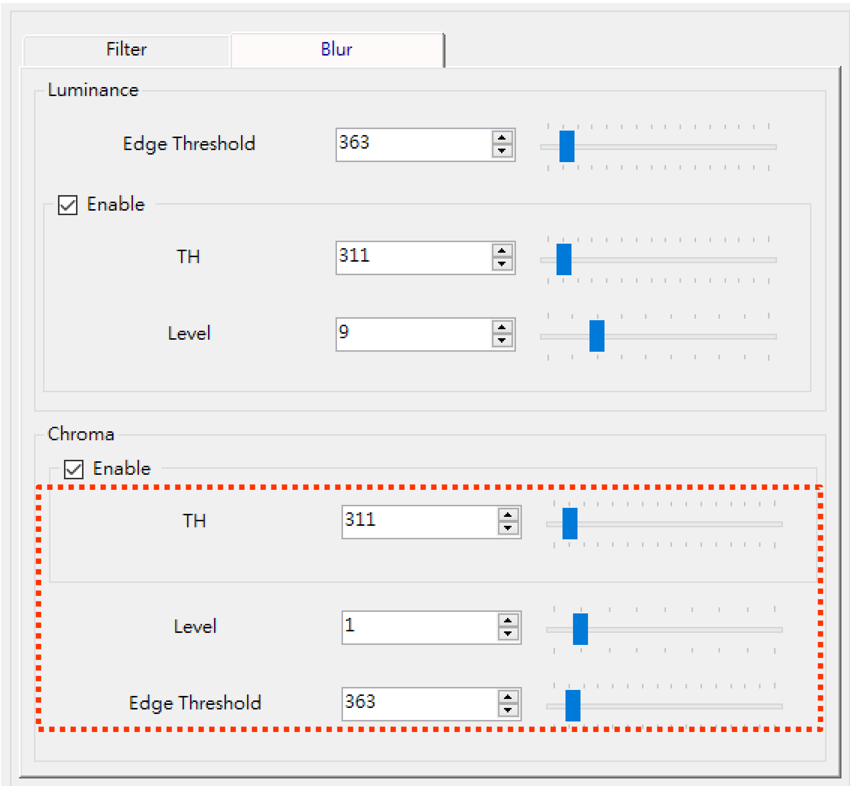


Fig. 5-59 CFAi Chroma filter

In this option is to reduce color aliasing by blurring chrominance. However, too strong setting will cause more error color instead.

5.8. Dynamic Tone Control

- DTC is used to automatic generate LTM curve、Scale curve and GTM curve according to the midtones gain and shadows gain.
  - DTC Limitation(default)
    - midtones gain 1.0x~8.0x
    - shadows gain 1.0x~4.0x.
- If midtones gain and shadows gain are around 1.0x, DTC will be bypass, and

directedly apply the LTM curve、Scale curve and GTM curve which are User defined in the LTM and GTM tuning block.

5.8.1. BV trigger

- There are three trigger zones by BV.
- You could select which zone to tune, and define the BV range by user.
  - BV -5000~-1500, define as night scene.
  - BV -1000~ 1400, define as indoor scene.
  - BV 2400~12000, define as outdoor scene.
- Weighting indicates which interval falls into.
- This trigger zones are sync with DTC、GTM and LTM blocks.

Select To Tune	BV : 5000	Weighting
☐	-5000 ~ -1500	0
☐	-1000 ~ 1400	0
☑	2400 ~ 12000	1

Fig. 5-60 BV Trigger Zone

5.8.2. DTC Setting

Please refer to Fig. 5.50 DTC setting

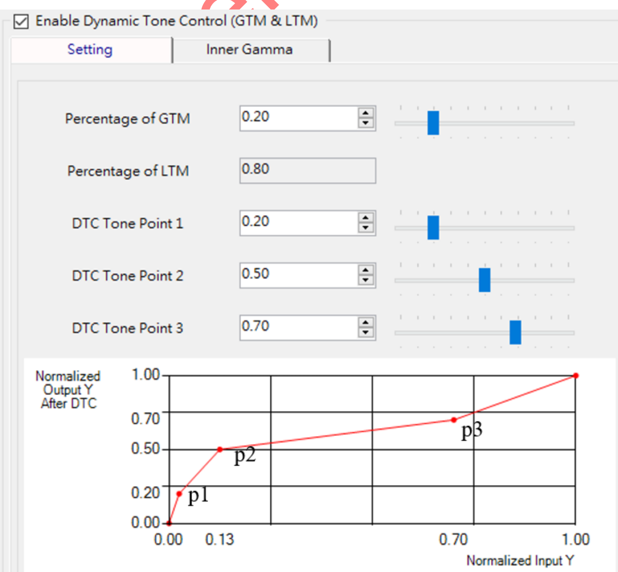


Fig. 5-61 DTC Setting

- Enable DTC, otherwise disable GTM and LTM. (Simulation only)
- Tune GTM percentage
  - Range:0~1
  - The percentage of brightness boost by GTM.

- Recommend setting
  - Night scene :0.5
  - Indoor scene: 0.35
  - Outdoor scene: 0.2
- Tune Tone Points1~3
  - Range:0~1
  - Control the tendency of DTC gain curve
    - 0~Point1: represent low key range, where the midtones gain and shadows gain taking effect.
    - Point1~Point2: represent middle key range, where the midtones gain taking effect.
    - Point2~Point3: represent middle to high key range, where the midtones gain is progressively reduced to 1.0x;
  - Recommend setting: (0.2,0.5,0.7)

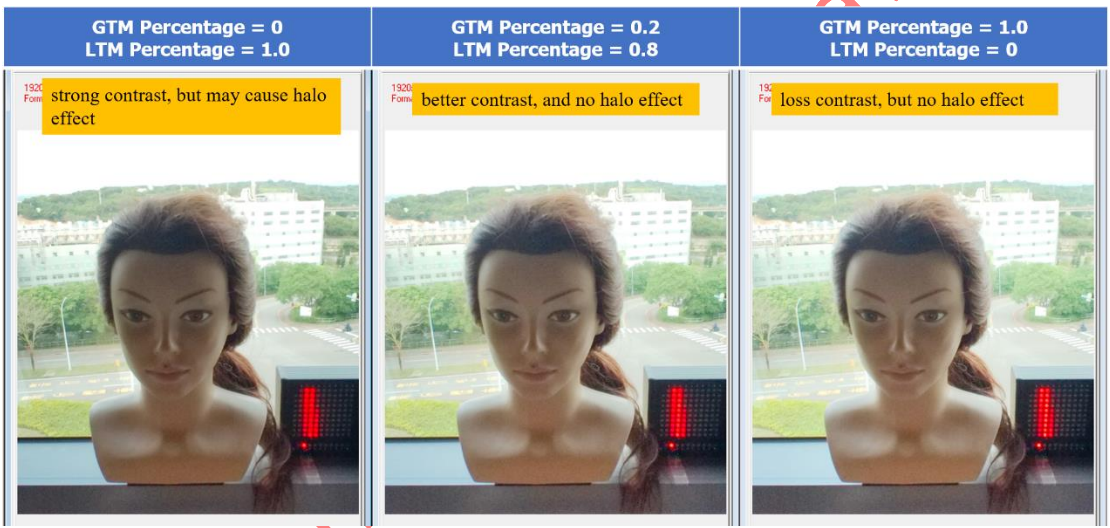


Fig. 5-62 The difference of GTM percentage when midtones gain = 4.0x、shadows gain = 2.0x

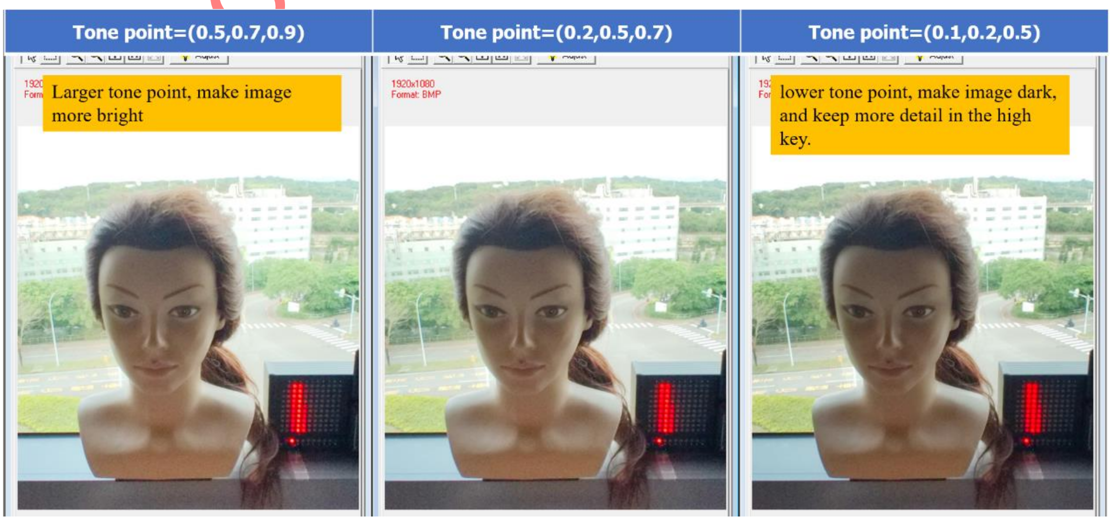


Fig. 5-63 The difference of Tone Point

5.8.3. Inner Gamma Setting

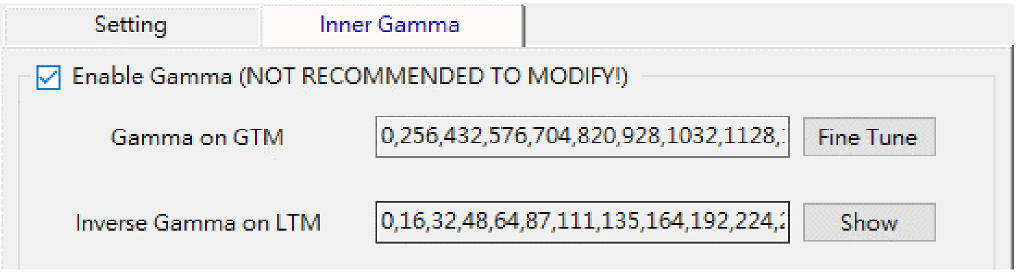


Fig. 5-64 Inner gamma setting

- The inner gamma is applied after GTM to compress image into 12bits.
- Keep low key detail by inner gamma.
- The inverse gamma will be automatic generated, and applied after LTM to inverse inner gamma.
  - Range:
    - Inner gamma: 16 bits in,12 bits output mapping.
    - Inverse inner gamma: 12 bits in,12 bits output mapping.
- Suggest to enable Gamma on GTM, otherwise apply linear gamma on GTM
- Not recommended to modify.

5.9. GTM

- GTM applies global gain curve to each pixel to enhance brightness according to the pseudo Y index.
- If the midtone gain and shadows gain are around 1.0x, User can define the global gain curve in this block.
- After apply gain curve, there is an inner gamma on GTM to compress 16bits RGBs into 12bits.
- Convert RGBs to YCC420s format for NRE.

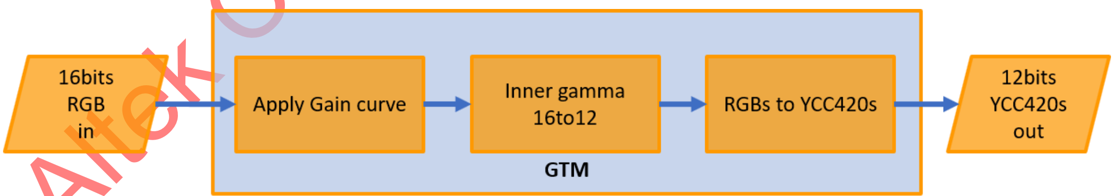


Fig. 5-65 The flow of GTM

5.9.1. Tool Bar UI

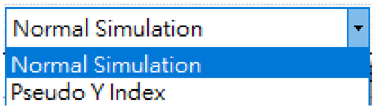


Fig. 5-66 UI of Preview Option

- Preview Option

- Normal Simulation:
  - show preview as GTM result.
- Pseudo Y index:
  - show preview as pseudo Y index map for tuning.
  - Move cursor on the preview, get pseudo Y index for tuning user defined gtm curve (Fig. 5-67).
  -

Fig. 5-67 Pseudo Y index Map from preview

5.9.2. RGBs to Pseudo Y

Please refer to Fig. 5.57 the RGBs to pseudo Y.

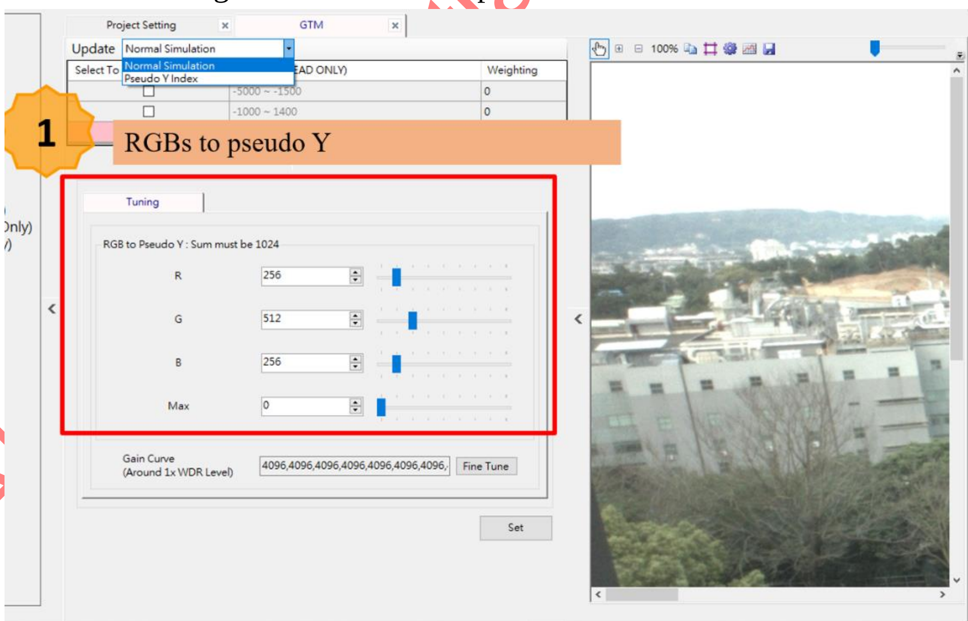


Fig. 5-68 RGBs to Pseudo Y Interface

- RGBs to Pseudo Y
  - Before Global tone mapping, calculate pseudo Y to LUT.
  - Finetune c1~c4, the coefficients of R,G,B and max(R,G,B).
    - Range:0~2047
    - RGB to Pseudo Y coefficients, sum must be 1024.

- Pseudo Y =(R*c1+ G*c2+B*c3+max(R,G,B)*c4)>>10;
- Default = (256,512,256,0)

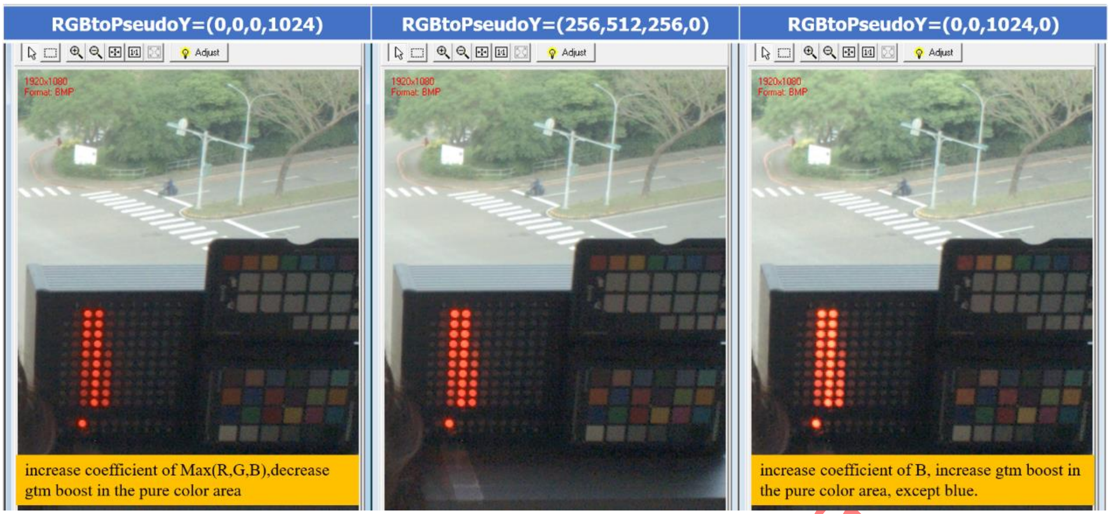


Fig. 5-69 The diff of coefficients

5.9.3. User Defined GTM Gain Curve

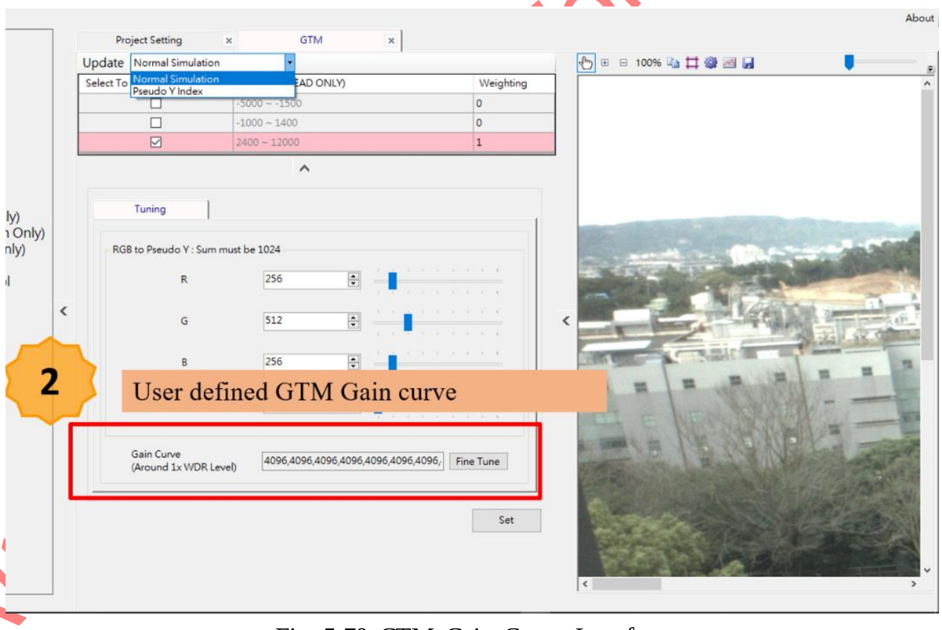


Fig. 5-70 GTM Gain Curve Interface

- User Defined Gain Curve
  - Finetune user defined gain curve according to the pseudo Y index.
  - Effective conditions:
    - midtone gain and shadows gain are around 1.0x.
  - Range:4096(1.0x) ~131071(31.99x)
  - pseudo Y index could be got from preview in the tuning tool.
  - Default = 4096(1.0x) for all pseudo Y index.

- Example for user defined gain curve
  - boost up dark area and face area.
    - Find the pseudo Y index around face and dark area. (around 0~20)
    - Increase gain around pseudo Y index 0~20.
    - Gain curve should be smooth to avoid brightness inversion.

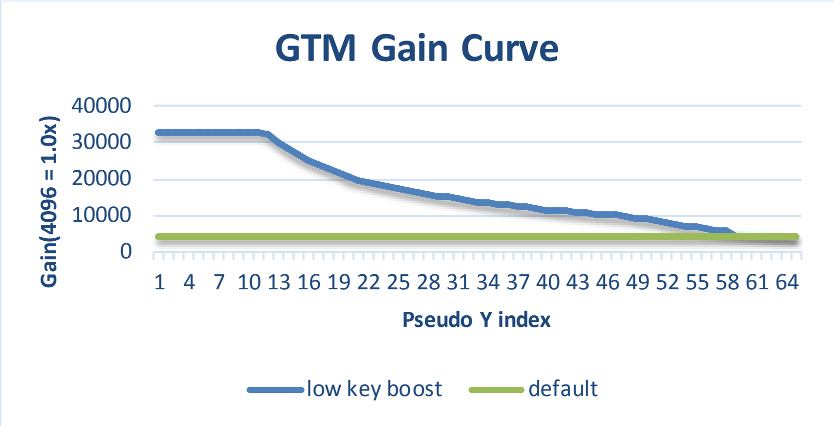


Fig. 5-71 gain curve

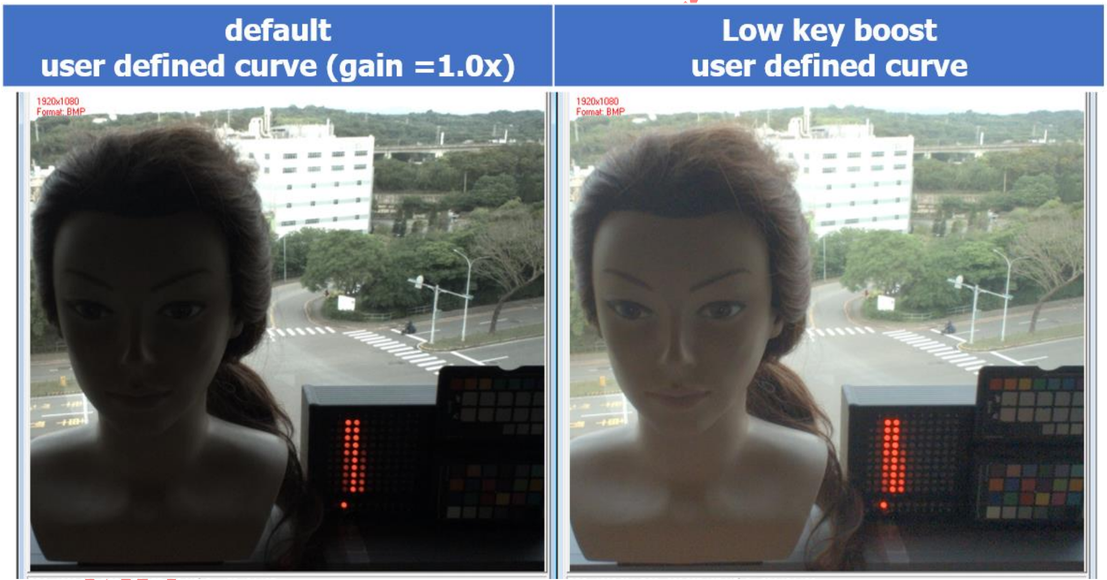


Fig. 5-72 GTM result

5.10. NRE Multi-Layer NR

This function allows user to remove noise in each channel (Y, U, and V). NRE is 4 layers parameter. Every layer corresponded to previous bottom layer. So L4 parameter should be decided first. Only Y has Edge Refinement.

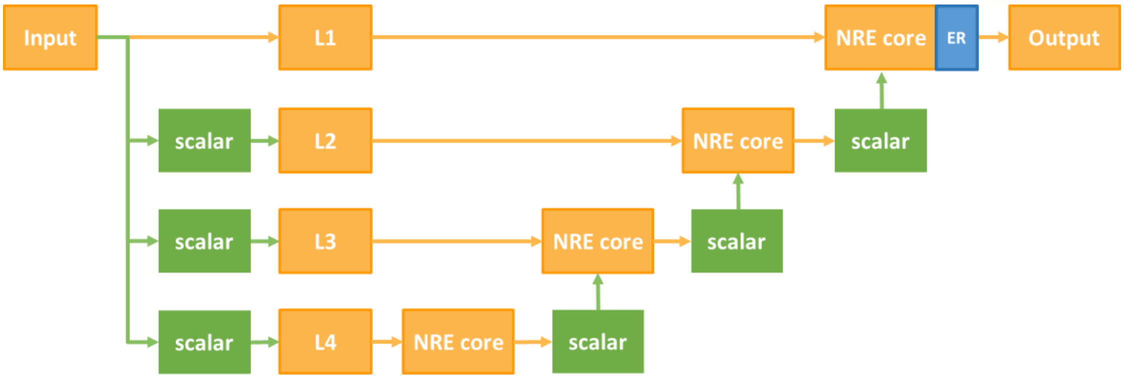


Fig. 5-73 NRE Architecture

Multi-layer architecture reduces noise by band. Different layer is response to different noise band.

- User can adjust level on each layer to control quality.
- Reduce low frequency noise required larger mask, or need more layers.

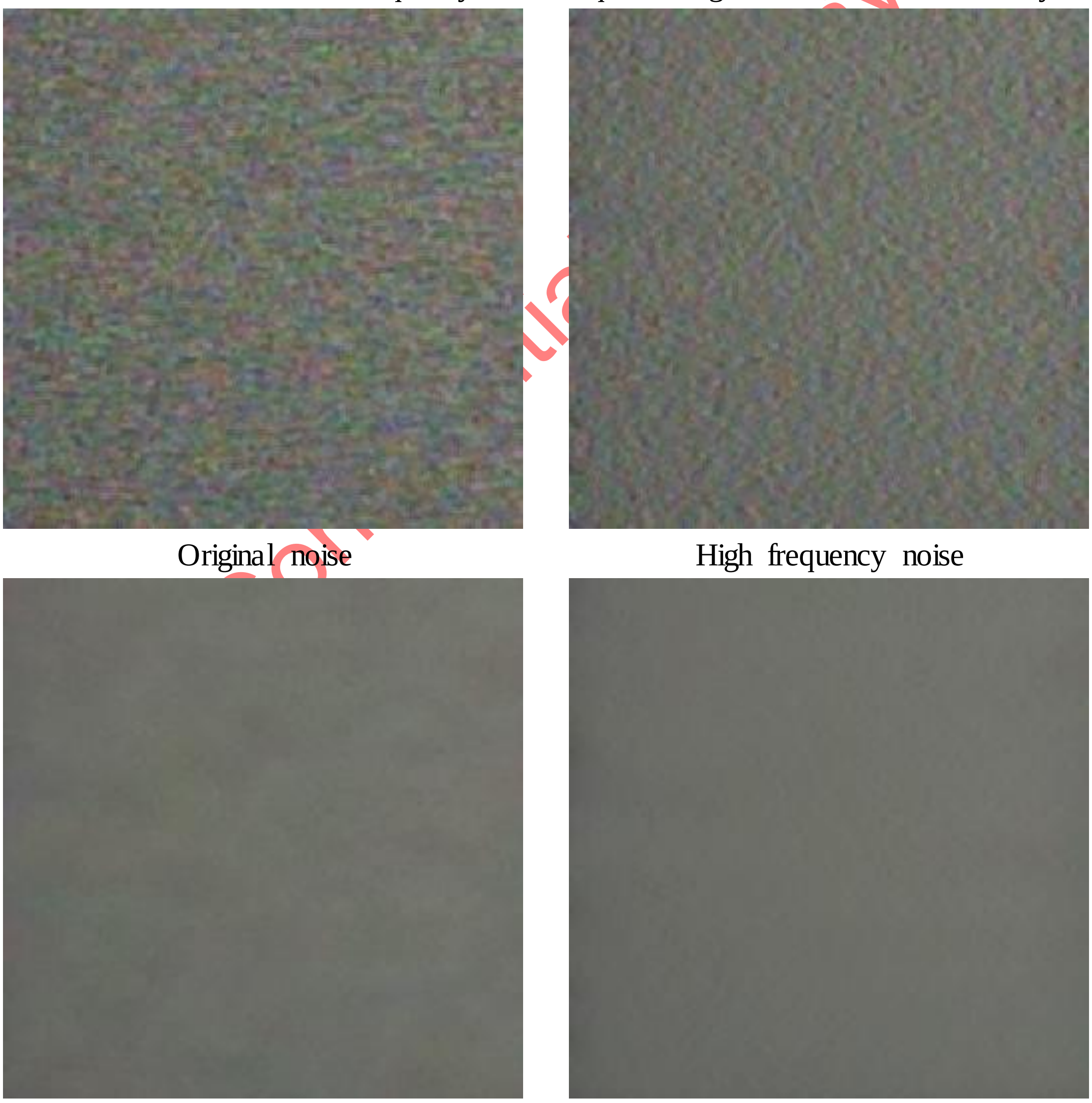


Fig. 5-74 NRE Architecture CbCr

5.10.1. Major follow

- Major tuning follow as below
- From layer 4 to layer 1
- For Y, Cb, Cr

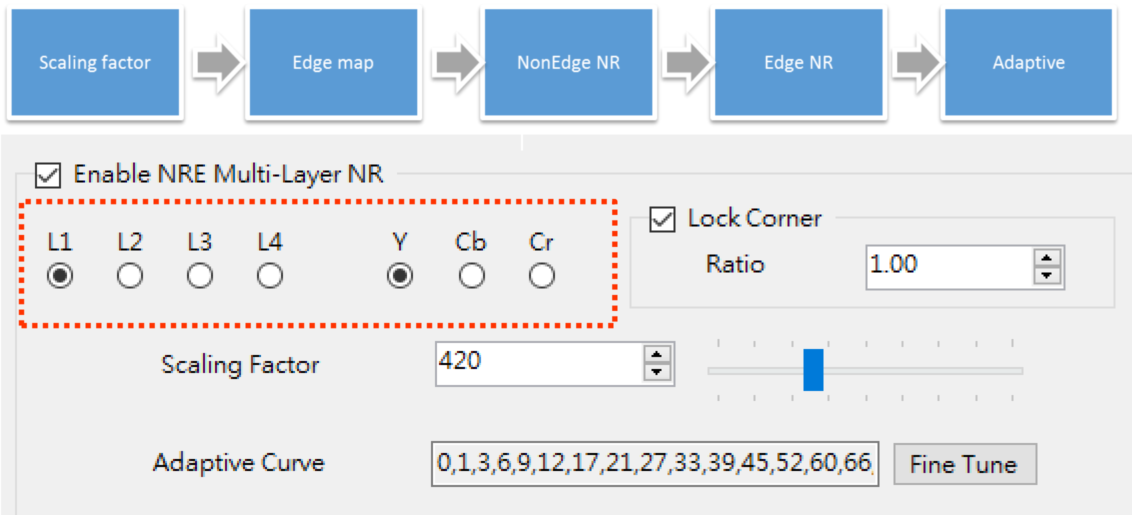


Fig. 5-75 NRE tuning flow

5.10.2. Tuning follow 1

- Decide equivalent mask size by choose “Scaling Factor”
  - ☐ Smaller scaling factor means larger mask size, and larger mask can remove lower frequency noise
  - ☐ To check suitable scaling factor
    - Select last layer output
    - Make Blend Mode to 2
    - Make Filter 2x to max level
    - Adjust a min scaling factor that flat area noise is not obviously
  - ☐ If you are set the strongest parameter but low frequency noise still left, then you should to decrease scaling factor.

Fig. 5-76 NRE scaling factor

5.10.3. Tuning follow 2

- Show edge map and adjust Edge Th
  - ☐ Adjust Edge Th on different pixel intensity
  - ☐ Set corner ratio for auto adjust corner para
    - Corner ratio would be related to shading gain on corner

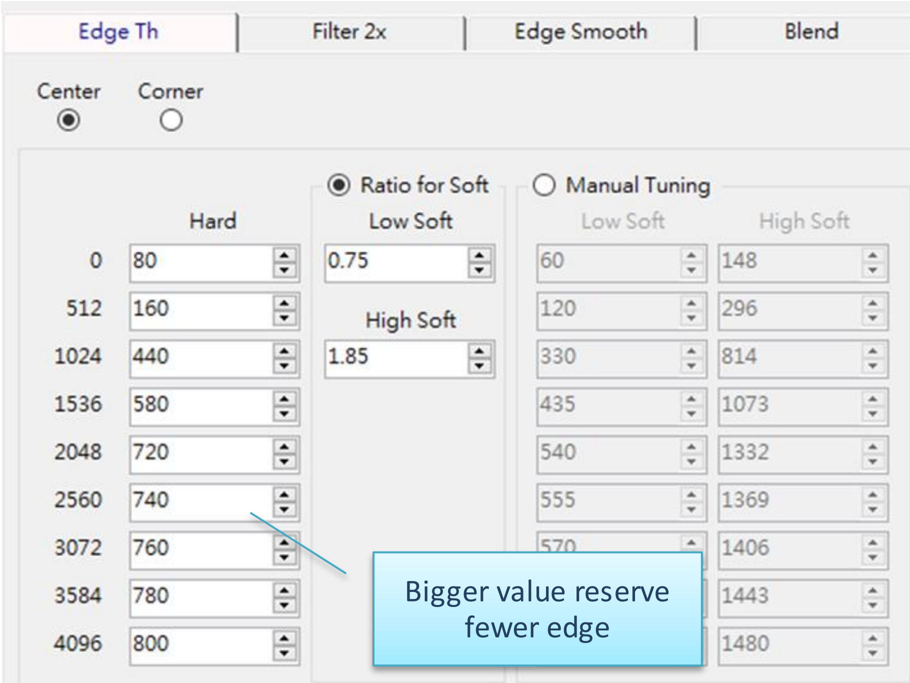


Fig. 5-77 NRE edge threshold

Same level on center & corner

Suppress corner

Fig. 5-78 NRE edge threshold example

5.10.4. Tuning follow 3

- Relation of Filter 2x, Edge smooth and Blend
  - Take edge map, pixel position, pixel intensity…etc info to decide weighting for blending 2 filters' result.
    - For example: If you disable Filter 2x but blend all weight on Filter 2x, even set strongest setting on Edge smooth you will get a noisy image.

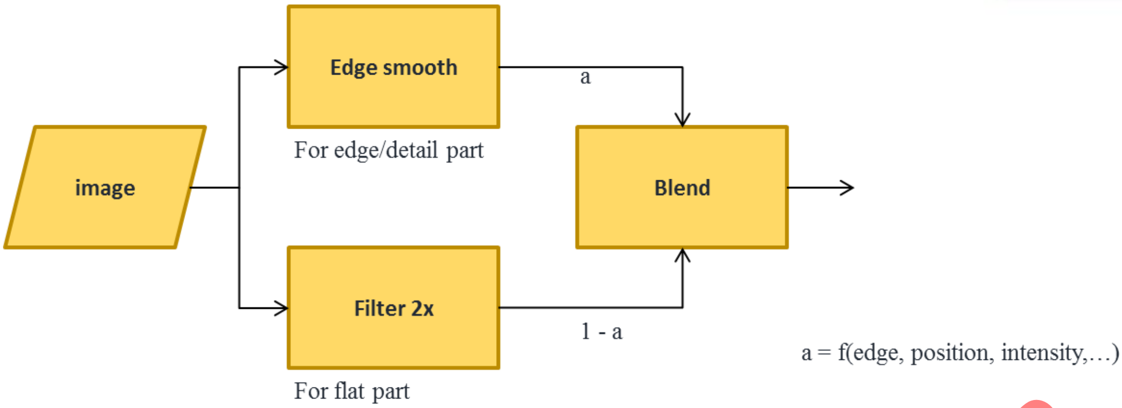


Fig. 5-79 NRE filter & blend

5.10.5. Tuning follow 4

- ■ Filter 2x
  - ☐ Mode: filter type, 0~3 → weak ~strong
  - ☐ Threshold: smaller value preserve more edge. 5 segments by intensity.
- ■ For design purpose, is used on flat area. Suggest configure as stronger level.

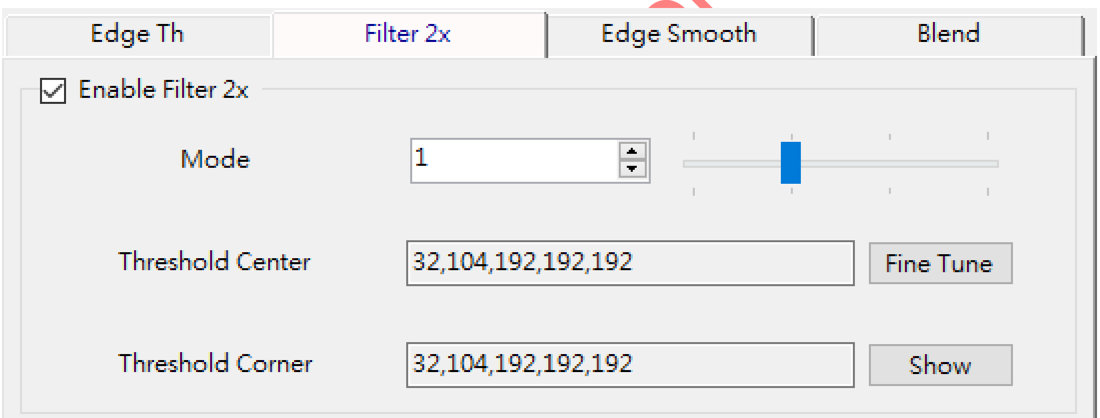


Fig. 5-80 NRE Filter 2x

5.10.6. Tuning follow 5

- ■ Edge Smooth
  - ☐ Threshold: smaller value preserve more edge. 5 segments by intensity.
  - ☐ N: transition level 0~15, bigger value makes less jaggy but blurring.
  - ☐ NonEdge Mode: applied on non-edge part, 0~4 → weak ~strong
  - ☐ NonEdge Weight: applied on non-edge part, 0~255 → blur ~clear
- ■ For design purpose, is used on edge or detail area. Suggest configure to weak level.

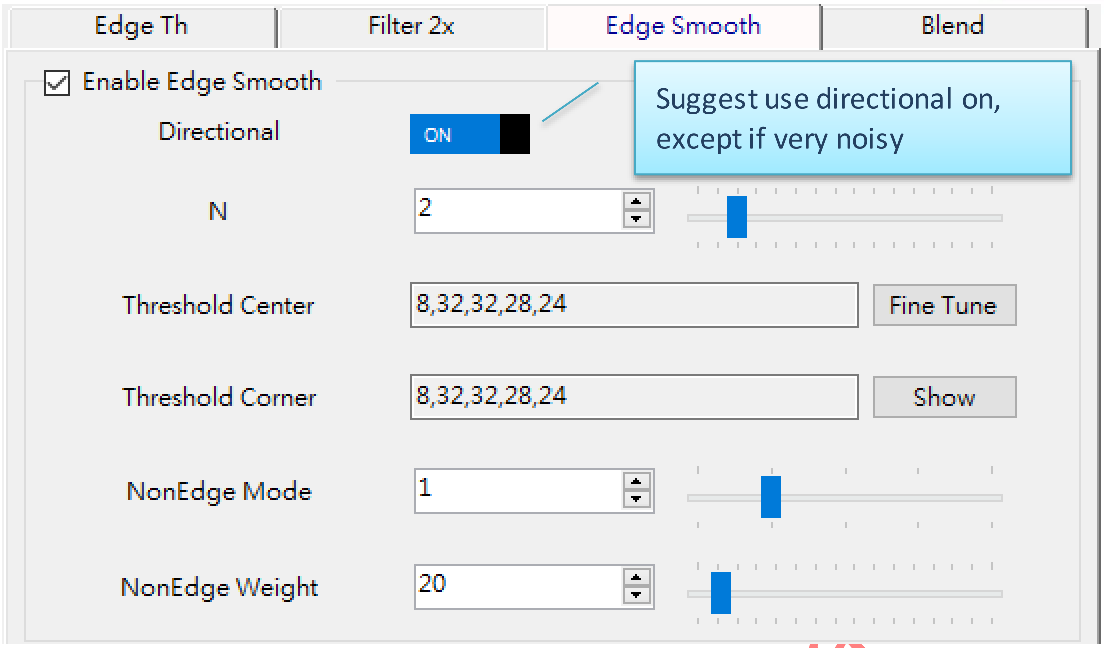
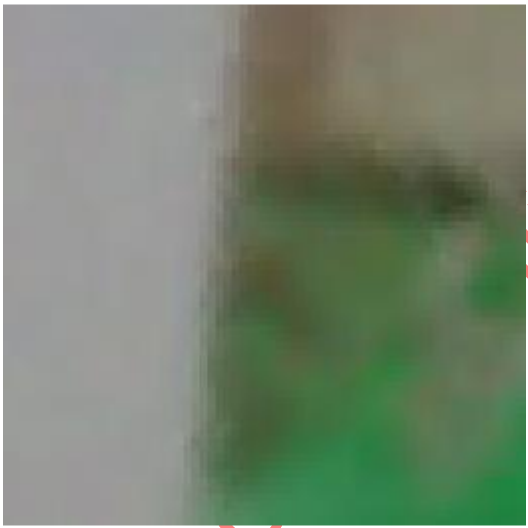
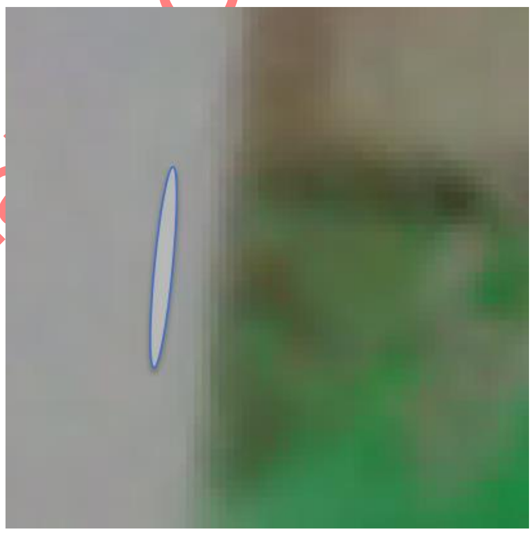


Fig. 5-81 NRE edge smooth

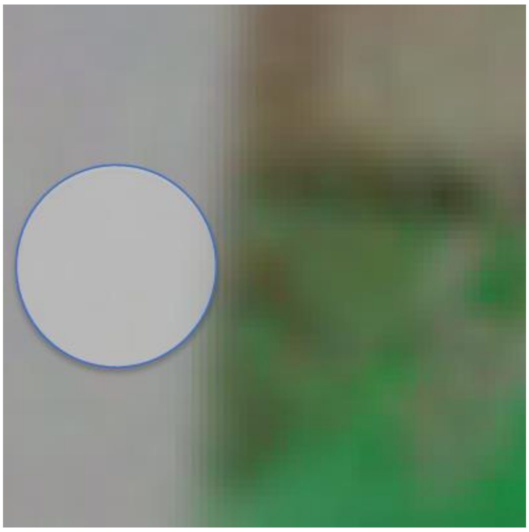


Off: TH0,N0



Directional: big TH,N0

Directional: big TH, big N



Local: big TH, N0

Local: big TH, big N

Fig. 5-82 NRE edge smooth example

5.10.7. Tuning follow 6

- Vertical filter
  - There are 2 Vertical filter units behind Filter 2x and Edge Smooth on layer 2,3,4
  - Filter 2x and Edge Smooth are process along horizontal. Vertical filter are process along vertical.
  - Due to horizontal and vertical are processed by different filters, the balance of these 2 directions should be take care. If one of filter is much strong than the other, image will induce moving blur feeling on this direction.

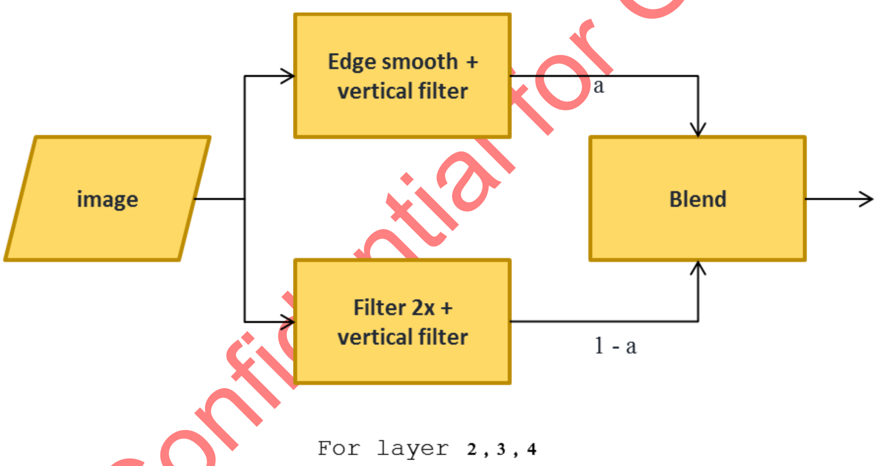


Fig. 5-83 NRE Vertical filter & blend

- Weight: apply weighting on Edge by pixel intensity
  - 5 segments from dark to bright. Typical value is 1024. Small value mapping to strong NR.
- Edge: 1~65535, small value mapping to strong NR.
  - Different level on 8 directions.
- Alpha: basic NR level 0~65535. No matter condition, at least applying this NR level. Big value mapping to strong NR
  - Different level on 8 directions.
  - We often use this item to control H/V balance

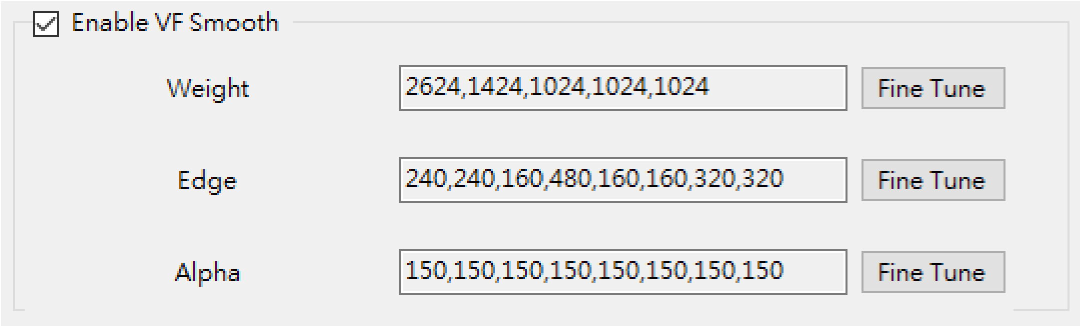


Fig. 5-84 NRE Vertical filter

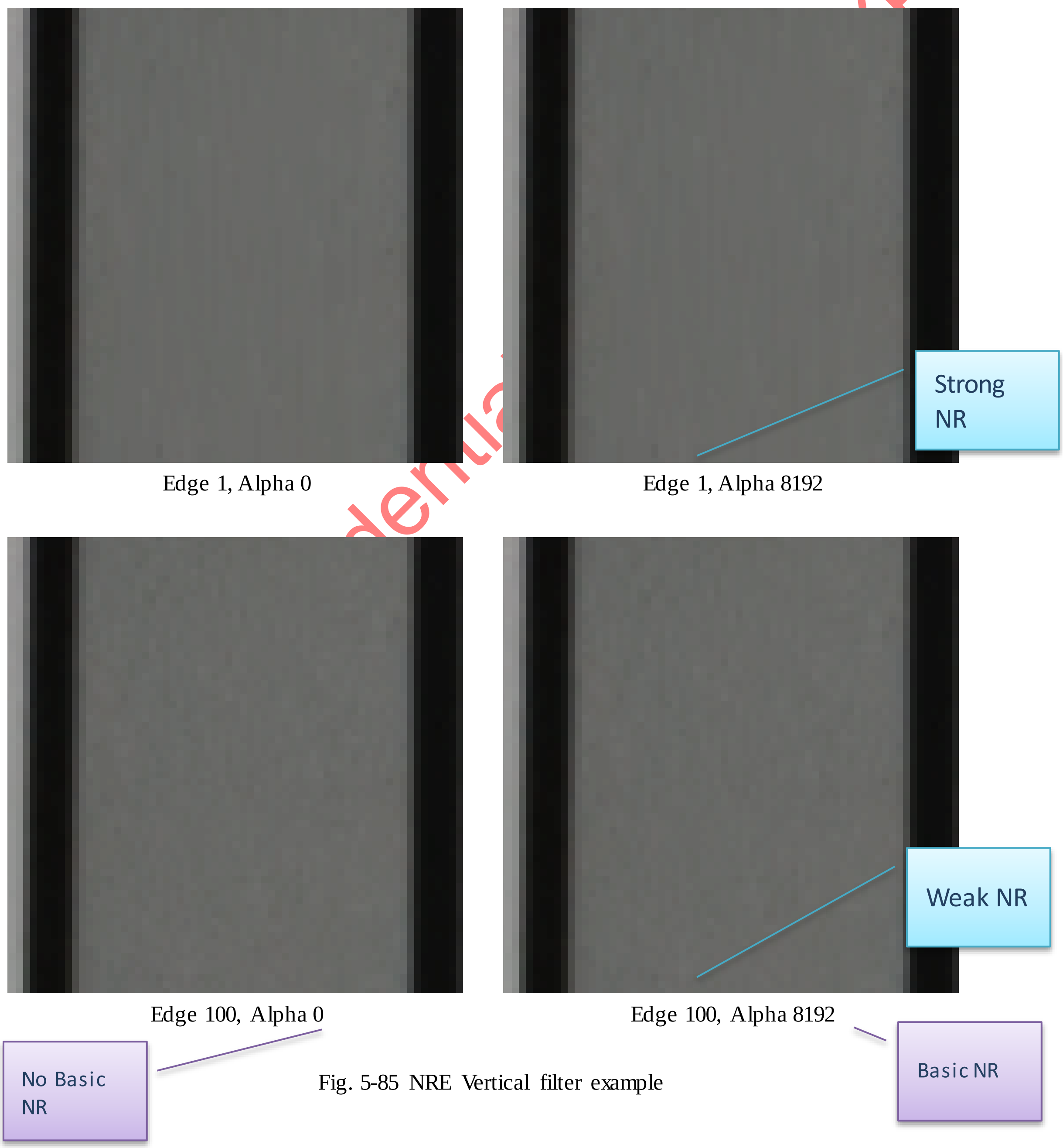


Fig. 5-85 NRE Vertical filter example

5.10.8. Tuning follow 7

- Blend
  - Hard : in general is 255
  - Soft : maybe 75% of Hard
  - NonEdge : weighting is changed depended on pixel intensity
    - 0 is weighted to Filter 2x
    - 255 is weighted to Edge smooth
    - Directional : different level on 8 ways
  - Adaptive Weight : Stronger on corner

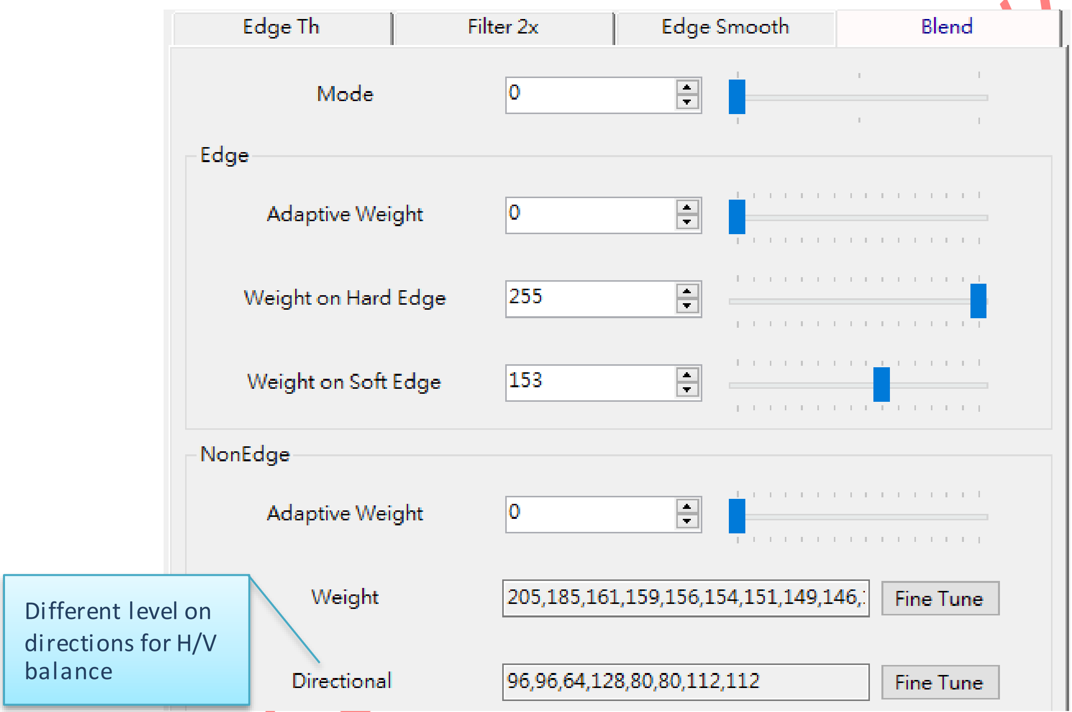
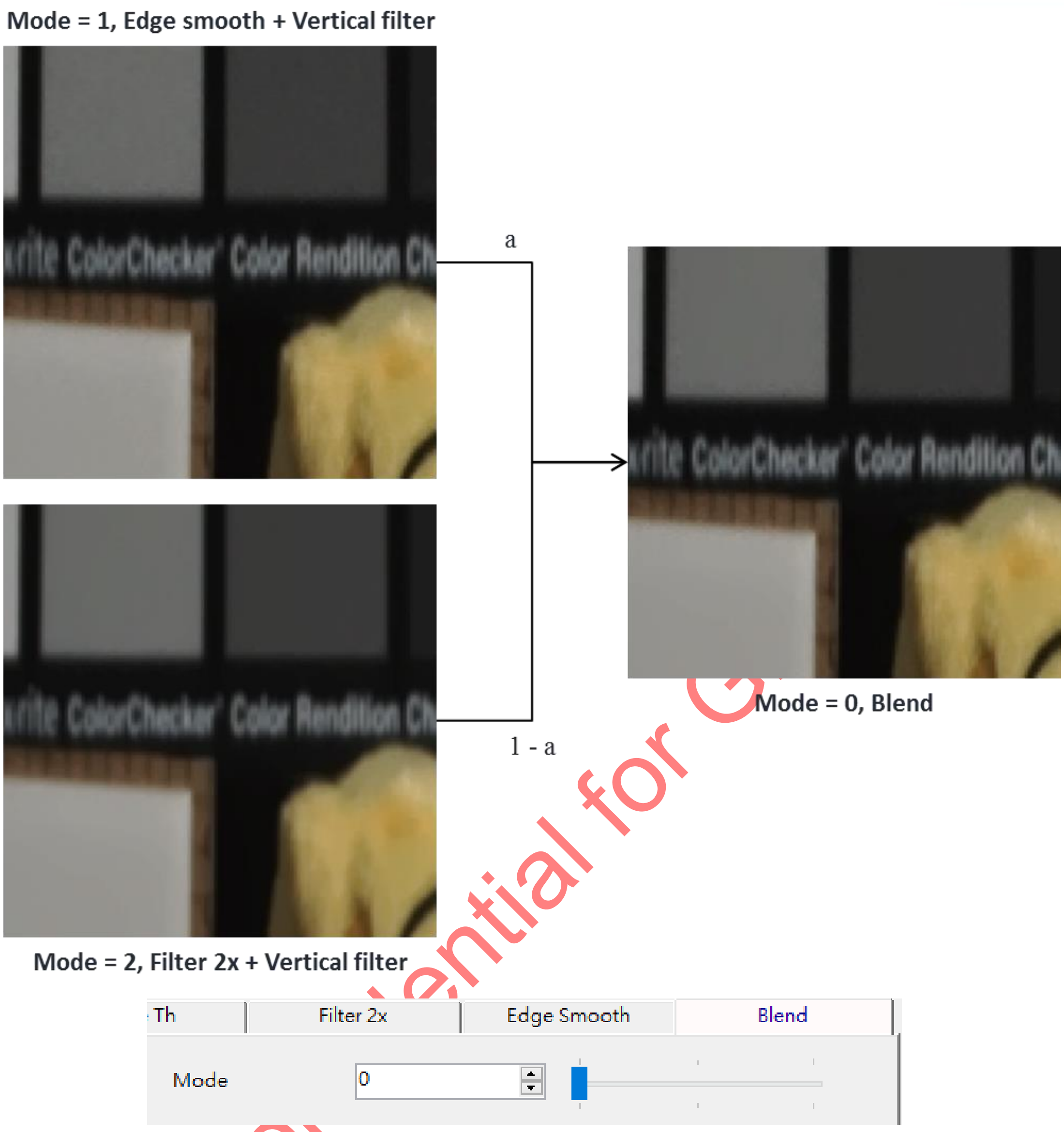


Fig. 5-86 NRE Blend

You can switch blend mode to see the effect come from Edge Smooth & Filter 2x. That will help judge what filter needs to be fine tune.

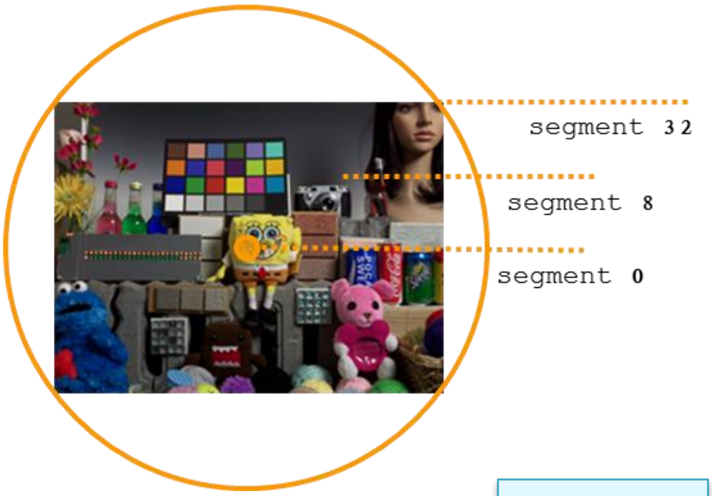


Switch mode to check respective result.

Fig. 5-87 NRE Blend example

5.10.9. Tuning follow 8

- Decide Adaptive Curve
  - ☐ This curve is uniform. Image center is at segment 0. However, half radius is at segment 8. This is to reserve more segments for corner tuning.
  - ☐ In general setting, suggest last segment value is 255
  - ☐ The trend of curve could refer to shading gain.



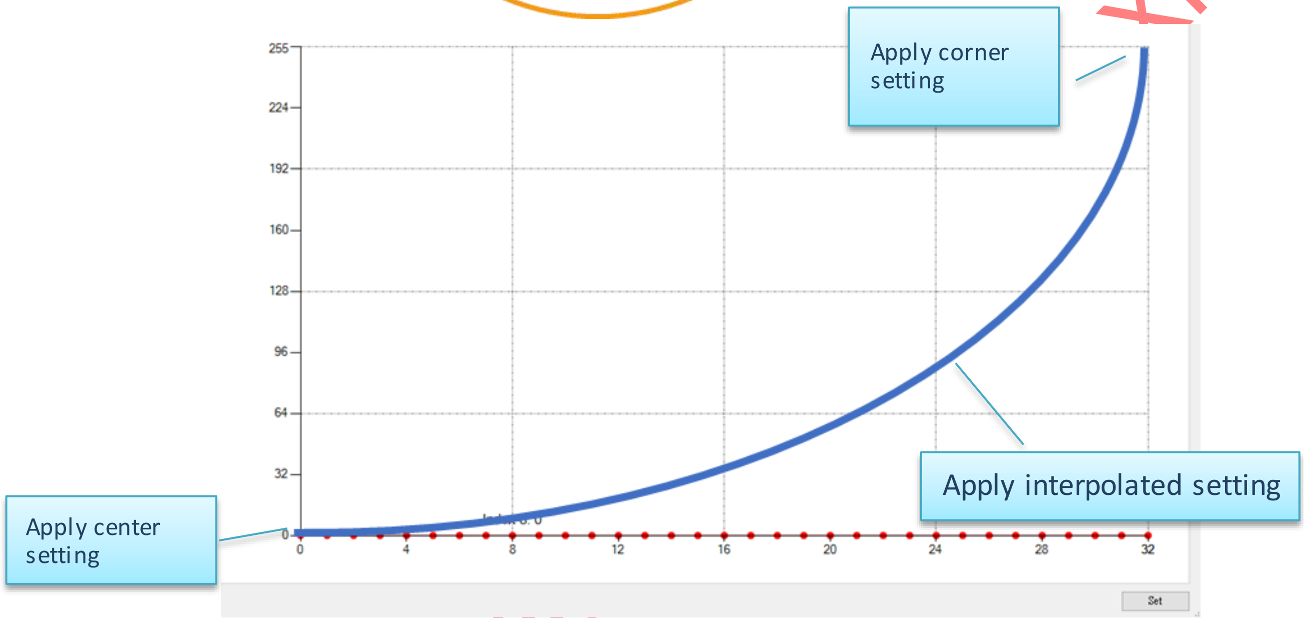


Fig. 5-88 NRE adaptive

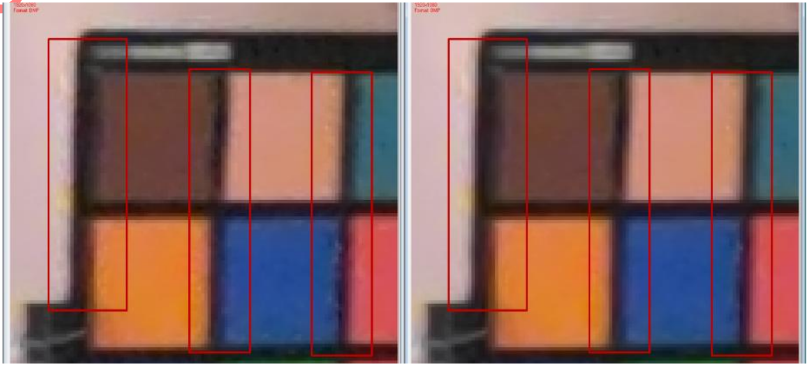
Each segment is mapping to image's radius as below:

segment	radius
0	0
1	0.176777
2	0.25
3	0.306186
4	0.353553
5	0.395285
6	0.433013
7	0.467707
8	0.5
9	0.53033
10	0.559017

11	0.586302
12	0.612372
13	0.637377
14	0.661438
15	0.684653
16	0.707107
17	0.728869
18	0.75
19	0.770552
20	0.790569
21	0.810093
22	0.829156
23	0.847791
24	0.866025
25	0.883883
26	0.901388
27	0.918559
28	0.935414
29	0.951972
30	0.968246
31	0.984251
32	1

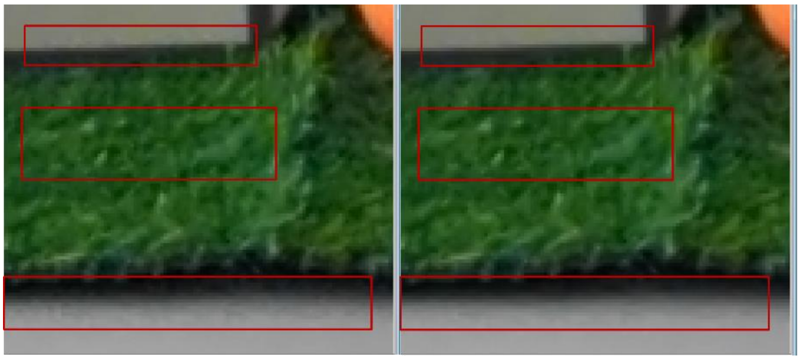
5.11. NRE Edge Refine

We improve the dirty edge by Edge Refinement. And it only works on one layer of the Y channel. The effect is shown in the previous section Fig. 5-89. We try to improve the dirty edge problem. At the same time, we try not to lose the detail of the part. As shown in the Fig. 5-90.



(a) w/o ER (b) w/ ER

Fig. 5-89 The effect of ER.



(a) w/o ER (b) w/ ER

Fig. 5-90 The effect of ER.

5.11.1. Interface Introduction

- Normal simulation: this output includes two functions. (NRE and ER).
- Debug information: we provide five debug information for user, as Fig. 5-91
- Tuning information: please follow NRE flag setting
- ER Flag (Enable NRE Edge Refine): we can observe the difference between w/o ER and w/ ER.
- Each debug information can be cross-referenced to the title of each sub-page, as Fig. 5-92

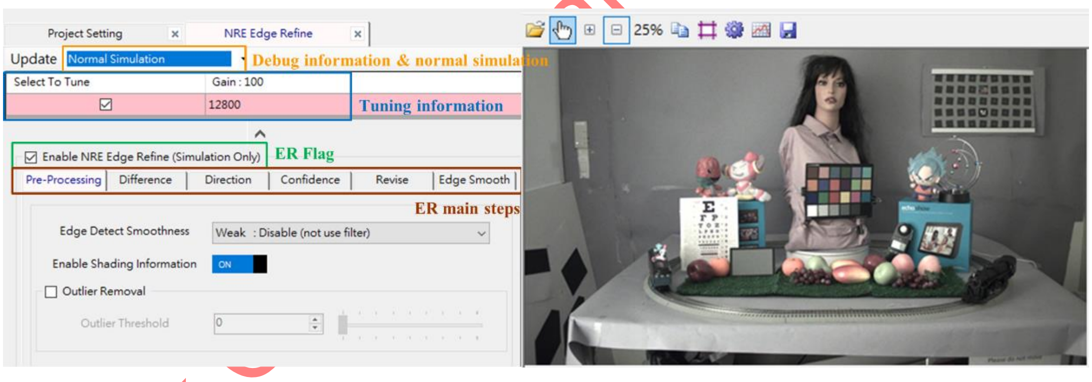


Fig. 5-91 About ER interface

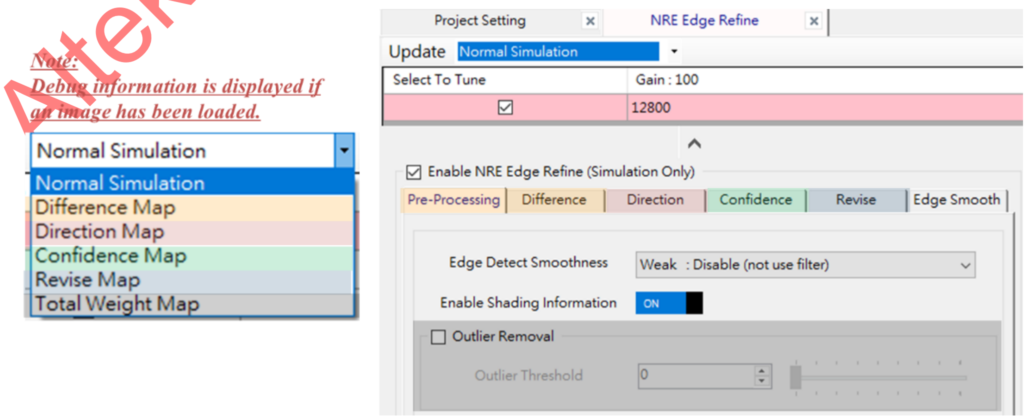


Fig. 5-92 ER debug information

5.11.2. Parameter: Pre-Processing section

Please refer to Fig. 5-93, the pre-processing page.

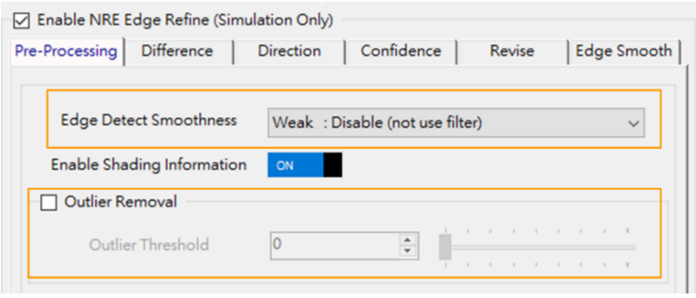


Fig. 5-93 The **Pre-Processing** page.

■ Edge Detection Smooth:

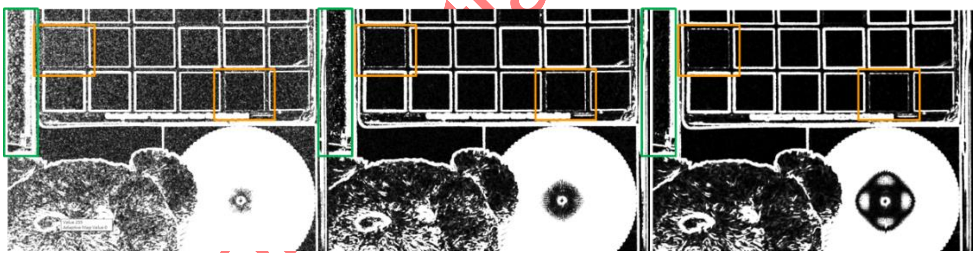
☐ Avoid noise affecting feature analysis, we use low pass filter to get cleaner image.

☐ Its result could be observed by the debug information ***Difference Map***.

☐ Three modes:

(c) not use filter (the most commonly used):
It's easily affected by noise, but the sensitivity of detection is better.

(d) Medium / average filter:
It's unaffected by noise, but the sensitivity of detection is also a little weaker.



(a) weak: not use filter (b) medium: gaussian filter (c) strong: average filter

Fig. 5-94 The results of the difference map with different filter mode.

■ Outlier Removal:

☐ It is used to eliminate abrupt points.

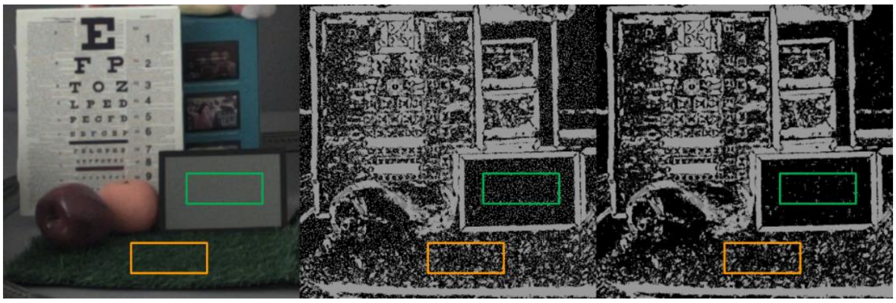
☐ Please note that we seldom use this feature because it is easier to loss the details.

☐ Its result could be observed by the debug information Difference Map.

☐ Tuning tips: Observe the pixel value which you want to eliminate. Set threshold with lower value. As shown in Fig. 5-95.

(a) High ISO, or blurred, less-detail images: on

(b) Low ISO, or more-detail image (ex: grass, leaves, hair, etc.): off or set "Outlier Threshold" with higher value.



(a) original input (b) outlier threshold = 0 (c) outlier threshold = 100

Fig. 5-95 The results of the total weight map with different thresholds.

5.11.3. Parameter: Difference section

Please refer to Fig. 5-96, the difference page

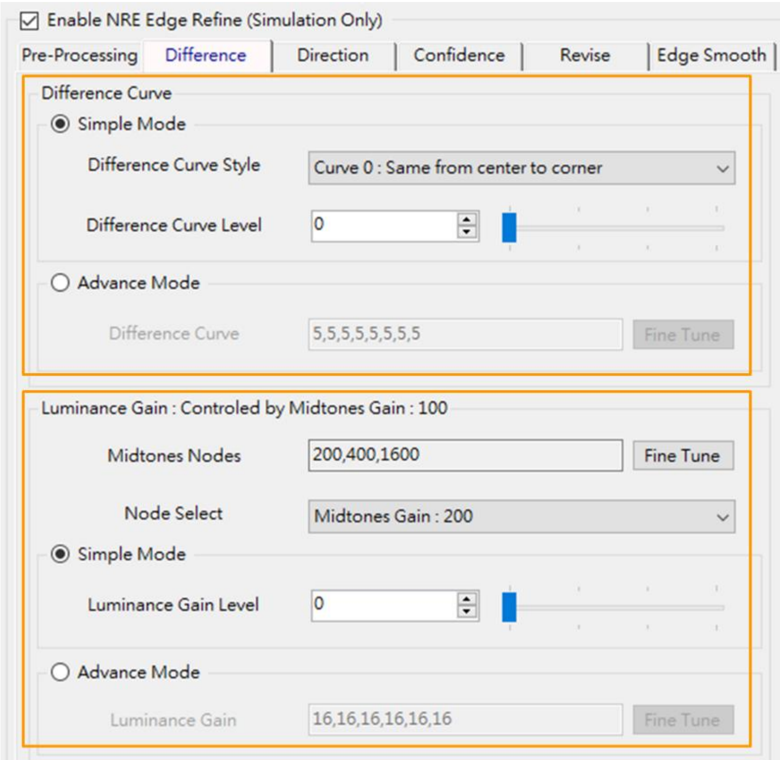


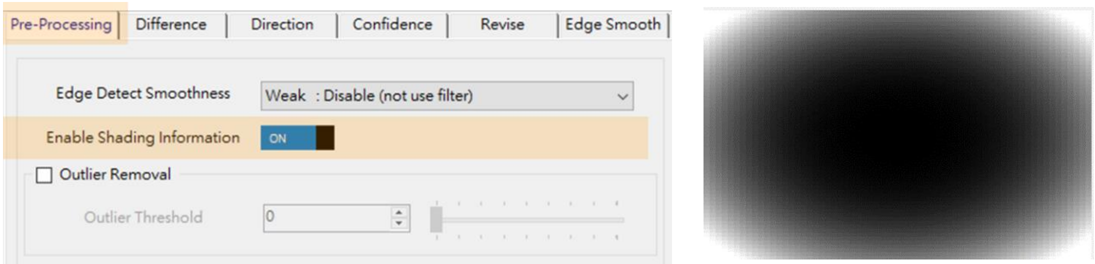
Fig. 5-96 The **Difference** page.

- ■ Difference Curve:
- ☐ It affects the detection strength of Difference Map.
- ☐ The higher the value seem the stronger gradient of edge.
- ☐ Besides, we provide simple and advance mode for user. In general, you can use the simple mode to observe the results of the difference map.

Simple mode:

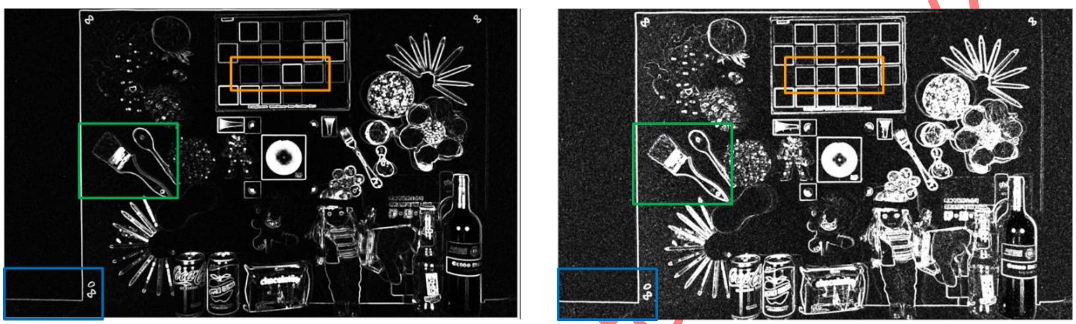
- ☐ Difference Curve Style: three style curves
- ☐ Difference Curve Level: provide four detection intensity for each style curve
- ☐ Note: If you want to have different levels of detection for the center and corners, please remember to open the shading flag (as Fig. 5-97).
- ☐ The effect of the difference map, as shown in Fig. 5-98. In general case, the

corner of the image is dirtier than the center. Therefore, we could choose curve 1 as our setting.



(a) shading flag (b) the adaptive map value of NRE

Fig. 5-97 shading flag information and adaptive map information



(a) Curve 0 & Level 0 (b) Curve 1 & Level 2

Fig. 5-98 Difference map results with different parameters (Difference curve & level).

advance mode: (we can adjust the parameter directly)

- ☐ If the shading flag is on, it means that you can fill in the corresponding difference value based on the adaptive map value of NRE.
- ☐ If the shading flag is off, it means that the difference map would only be calculated by the first difference value.
- ☐ Value range: 0~255

■ Luminance Gain:

The value of this parameter is determined by midtones, and mainly affects the detection intensity of the ***Difference Map***.

simple mode:

- ☐ Luminance Gain Level: four levels
- ☐ If the overall brightness difference is not significant, you can use curve 0.
- ☐ However, if the overall brightness difference is very large, curve 3 can be used. As shown in the Fig. 5-99.

advance mode: (we can adjust the parameter directly)

- ☐ We dive 0~255 into six internals (8, 16, 32, 64, 65) based on the pixel intensity of the original input.
- ☐ The fillable value range is 0~128, and the base is 16, which means the maximum

multiplication is 8 times.

(a) original input (b) curve 0 (c) curve 3

Fig. 5-99 Difference map results with different parameters (Luminance Gain).

■ Difference Threshold (not recommend to modify)

□ If Filter Mode≠0, we will merge two difference map information as our final difference map. As shown in the Fig. 5-100. Besides, we only show this UI when Filter Mode≠0, as shown in the Fig. 5-101 (a).

□ We dive 0~255 into five internals (10, 50, 100, 150) based on original input.

□ Difference Threshold 1:

□ The difference map I result is based on filter results image, the range is 0~255.

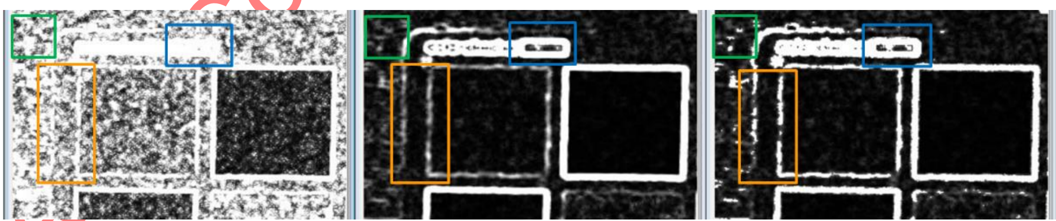
□ Difference Threshold 2:

□ The difference map II result is based on original image, the range is 0~255.

□ Tuning tips:

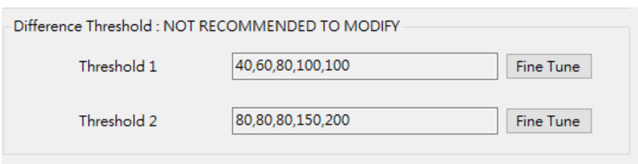
(a) We show the two related pieces of information about Difference Map I & II. As shown in the Fig. 5-101 (b).

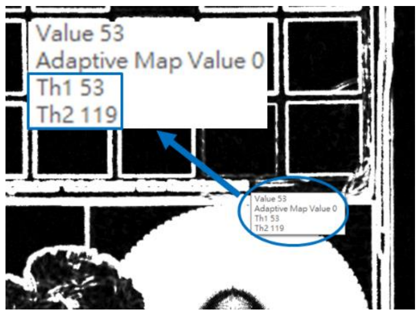
(b) You could fill the appropriate parameter based on original input value.



(a) original results (b) filter results (c) combine information

Fig. 5-100 The final combine Difference map results if Filter Mode≠0.





(a) Mapping to the position of a parameter on a page

(b) Two related pieces of information about Difference Map I & II.

Fig. 5-101 The Difference Threshold information

5.11.4. Parameter: Direction section

Please refer to Fig. 5-102, the direction page.

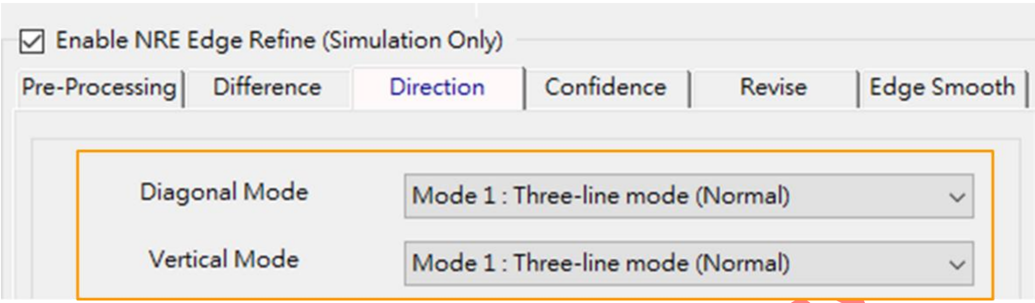


Fig. 5-102 The **Direction** page.

In order to avoid non-directional refining, we determine the direction of edge-pixel by edge detection.

- We can observe the ***Direction Map*** to check results. Besides, we will label different color for each direction. As shown in the Fig. 5-103.
- We provide three modes for the user, the difference between them is shown in the Fig. 5-104-Fig. 5-106.

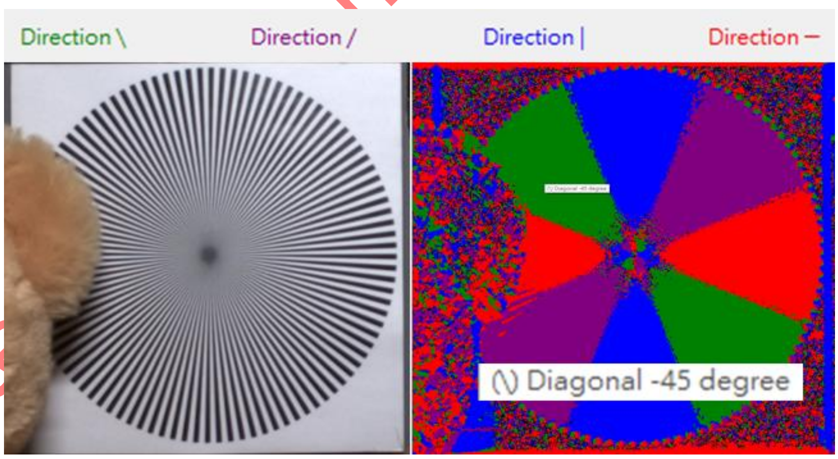
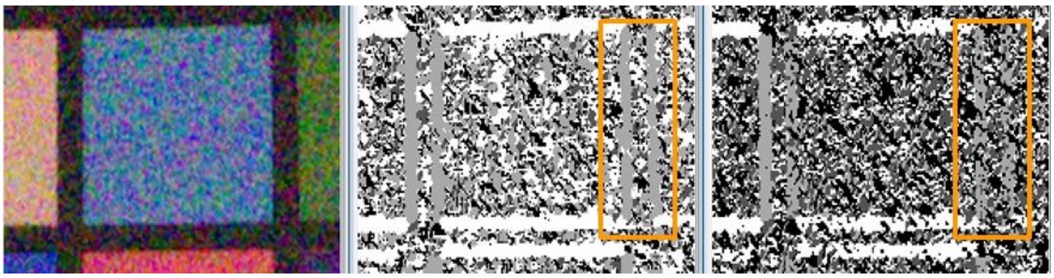
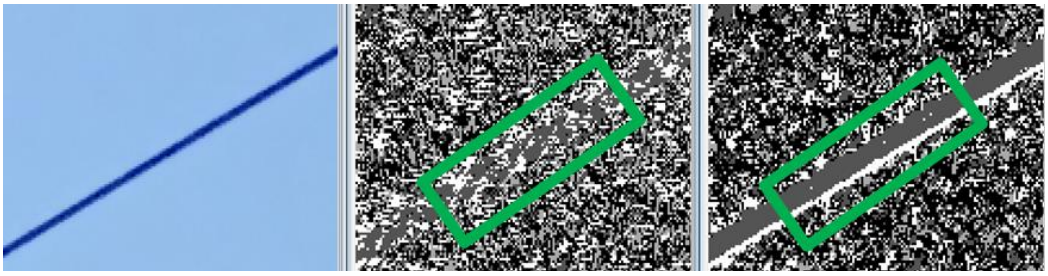


Fig. 5-103 Each direction with different label.



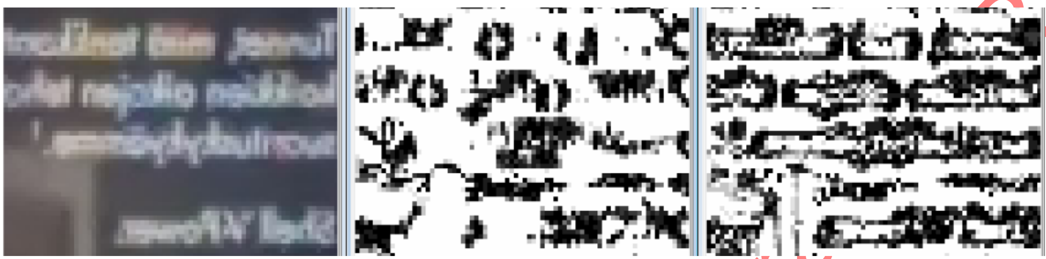
(a) original image (b) one-line mode (c) three-line form I

Fig. 5-104 The Direction map results for case 1



(a) original image (b) one-line mode (c) three-line form I

Fig. 5-105 The Direction map results for case 2



(a) original image (b) three-line mode I (c) three-line II

Fig. 5-106 The confidence map for case 3

5.11.5. Parameter: Confidence section

Please refer to Fig. 5-107, the confidence page.

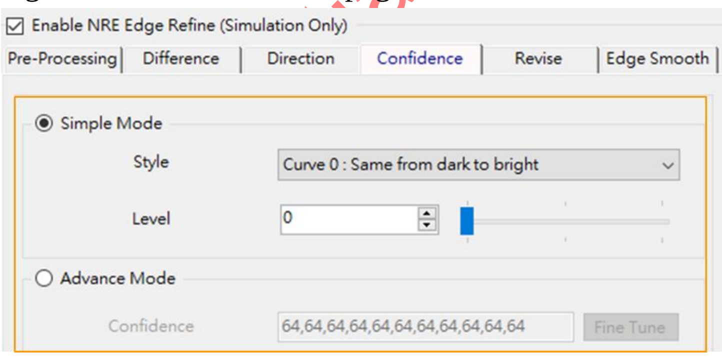


Fig. 5-107 The **Confidence** page.

We calculated the confidence based on the gradient values in each direction and adjust the confidence threshold by the brightness value. Its debug information is ***Confidence Map.***

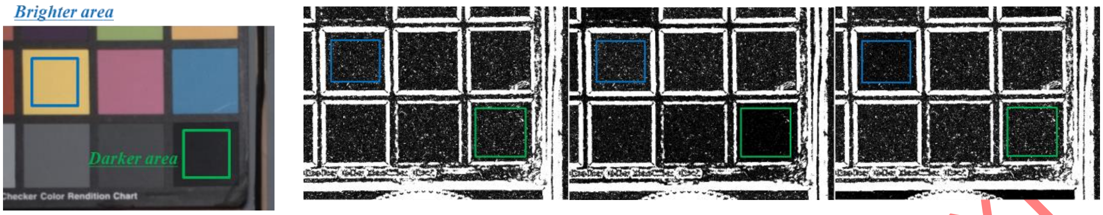
simple mode:

- ☐ Confidence style: three style curves, as shown in Fig. 5-108.
  - (a) Curve 1: The intensity of all pixel is with the same threshold.
  - (b) Curve 2: The condition is stricter in dark area.
  - (c) Curve 3: The condition is stricter in bright area.
- ☐ Confidence level: provide three detection intensities for each style curve

advance mode:

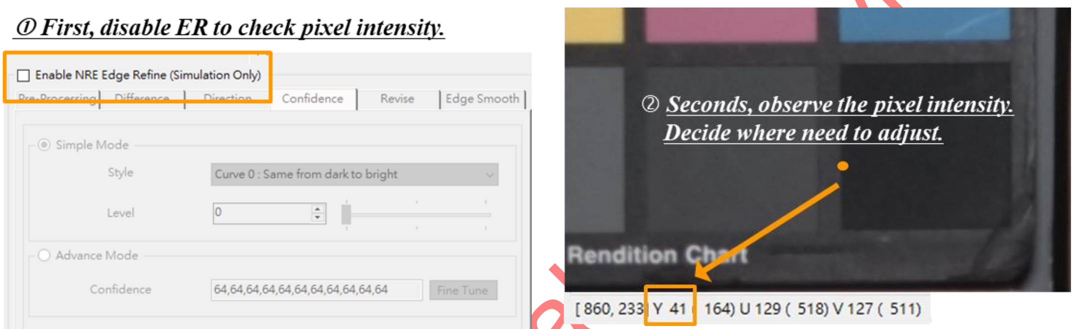
- ☐ In generally case, the brighter part of the middle area is not particularly adjusted, we mainly adjust the value to higher or lower for the darker areas.

- ☐ Range is 0 ~ 255, and its base is 64.
- ☐ The data range of the Confidence Map results is 0~11. The higher value, the higher confidence level.
- ☐ The steps of the advance mode tuning as Fig. 5-109.



(a) input image (b) curve0, level 0 (c) curve1, level 2 (d) curve2, level 2

Fig. 5-108 Confidence map results with different parameters (Confidence curve & level).



(a) first step (b) second step

Fig. 5-109 The steps of the advance mode tuning.

5.11.6. Parameter: Revise section

Please refer to Fig. 5-110, the revise page.

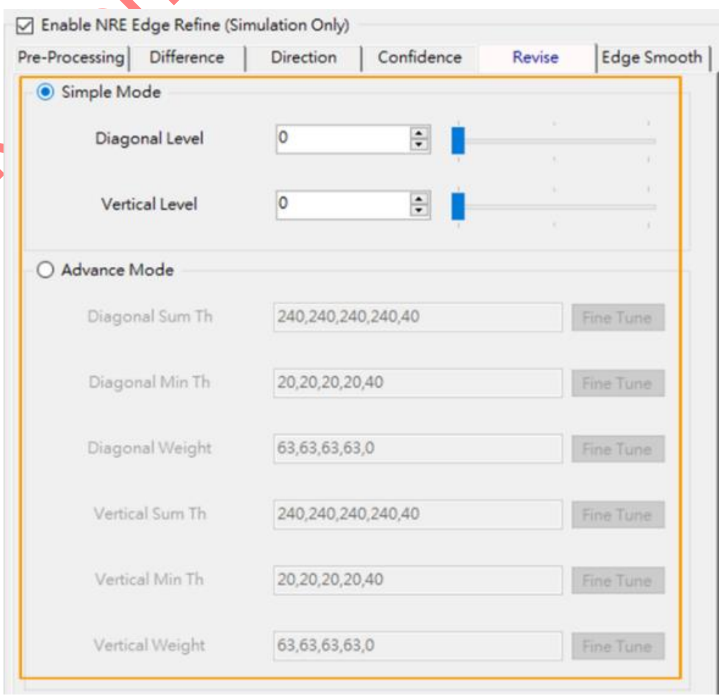


Fig. 5-110 The **Revise** page.

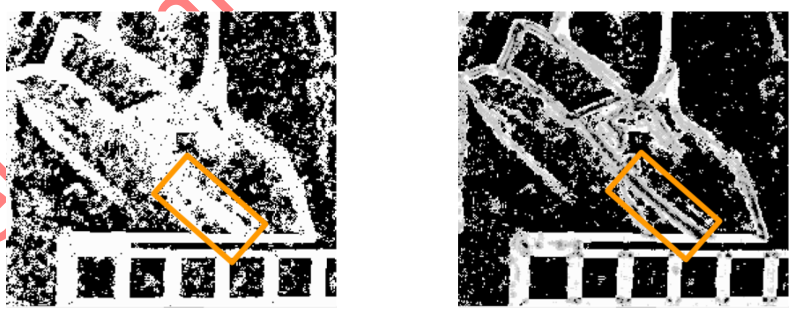
We can revise directional confidence standard by Diagonal/Vertical Sum Th, Diagonal/Vertical Min Th. Its debug information is ***Revise Map***.

simple mode

- ☐ Level 0~2: strict to lenient, their results as shown in Fig. 5-111.
- ☐ Diagonal and vertical directions can be adjusted separately.
  - (a) Diagonal direction includes ±45°
  - (b) Vertical direction includes vertical and horizontal.

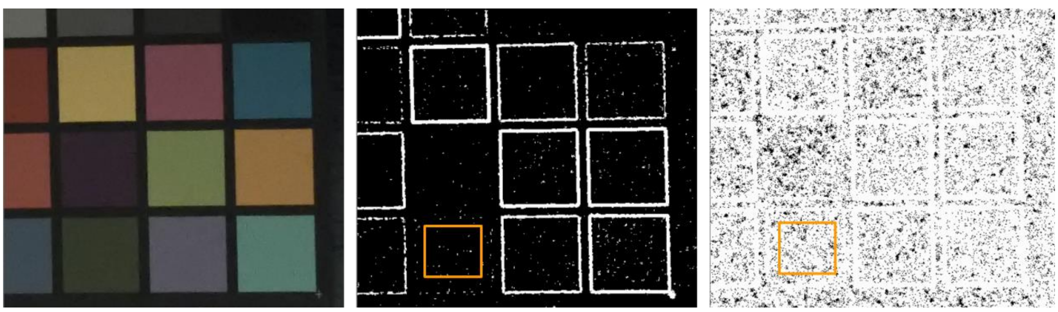
advance mode:

- ☐ Characteristics of higher confidence are with higher Sum Th, and the minor Min Th. Its weight could be lager.
- ☐ In general case, Sum Th, Weight is a decreasing value and Min Th is an increasing value.
- ☐ Data range is 0~1000.
- ☐ The last parameter of Diagonal/Vertical Sum Th (the effect is as follows):
  - (a) The recommendation can be determined by the overall noise level. As Fig. 5-112.
  - (b) If the image is dirty, you could set a higher value, but also need to check whether it causes the smoothness to be insufficient.
  - (c) If the image is clean, the value can be set lower.
- ☐ You can see the index information of the horizontal and vertical parameters where the pixel is. Besides, it also shows the conditional equation of the index. As Fig. 5-113



(a) Diagonal level 2 (b) Diagonal level 0

Fig. 5-111 The output of Revise map with different simple mode parameters.



(a) Original (dirty) (b) Parameter 1 (Diagonal/Vertical Sum Th [4] = 100) (c) Parameter 2 (Diagonal/Vertical Sum Th [4] = 20)

Fig. 5-112 The output of Revise map with the last parameter of Diagonal/Vertical Sum Th

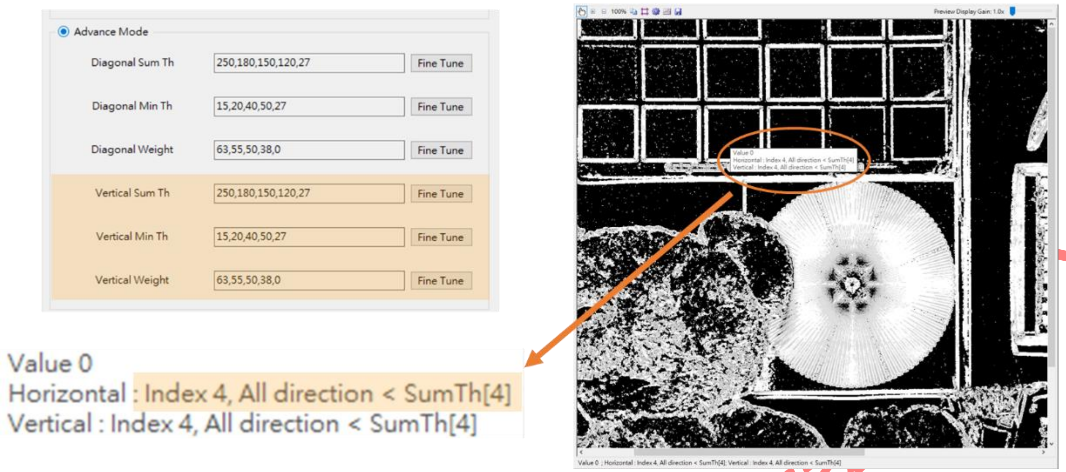


Fig. 5-113 Some debug information for tuning.

5.11.7. Parameter: Edge Smooth section

Please refer to Fig. 5-114, the edge smooth page.

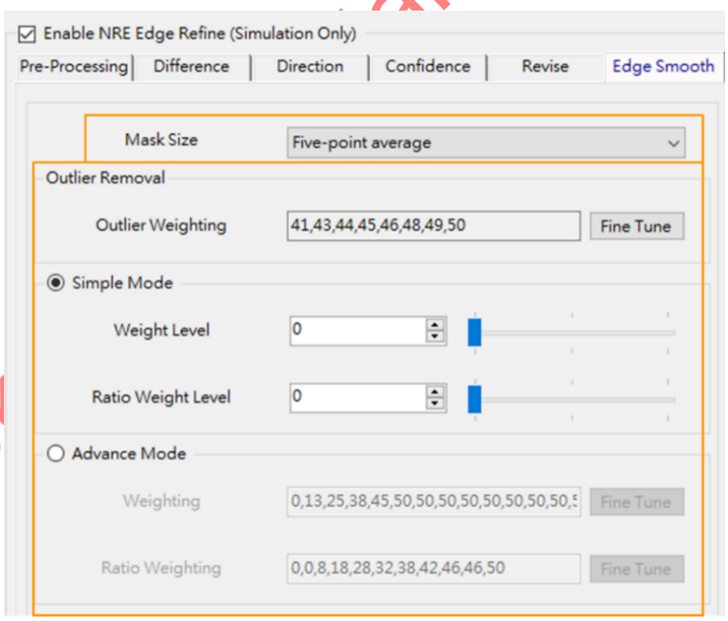
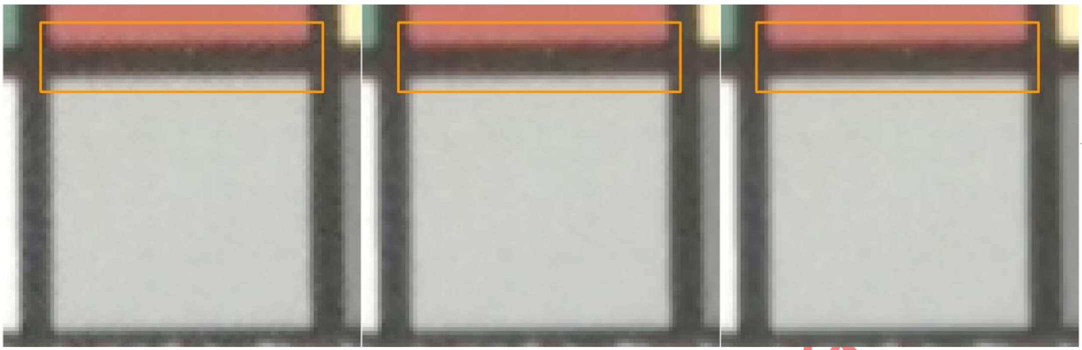


Fig. 5-114 The **Edge Smooth** page.

We determine how to smooth the edge in the part. Such as smooth mode and smooth weighting.

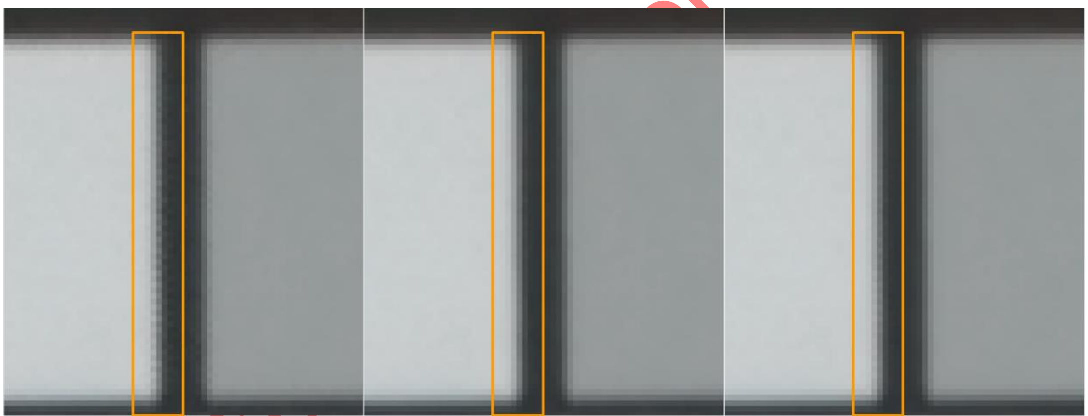
- ■ Mask size
- □ There are two selections which are respectively, three-point or five-point average for smooth mode.

- ☐ In general case, we usually use five-point average. However, you still can compare the results of the two modes and check which mode works better. As shown in Fig. 5-115.
- ☐ Please note: If you find your input like this (the rightmost picture), please check CFAI parameters or before ER's modulus. Our input is abnormal. This case is shown in Fig. 5-116.



(a) 50lux, w/o ER | (b) 50lux, w/ ER, three-point average | (c) 50lux, w/ ER, five-point average

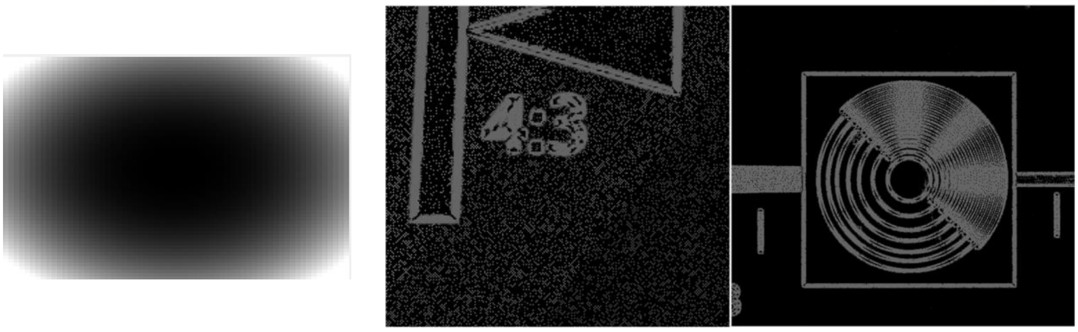
Fig. 5-115 The smooth results with different mask size mode



(a) 50lux, w/o ER | (b) 50lux, w/ ER, three-point average | (c) 50lux, w/ ER, five-point average

Fig. 5-116 The smooth results with different mask size mode

- ■ Outlier weighting (only could be adjusted when outlier removal is open)
- ☐ Debug information can be reference to the Total Weight Map.
- ☐ The smoothness of the outlier pixel is determined based on the adaptive curve of the NRE.
- ☐ In general, there is usually more detail in the center of the image, and the image may be dirtier around it. So, the outlier weight may be weaker at the center and stronger around it. As shown in Fig. 5-117.
- ☐ Note: If shading flag is off, we would only operate by the first value.



(a) Adaptive map, from NRE (b) w/ shading, total weight map at corner (c) w/ shading, total weight map at center

Fig. 5-117 The example tuning for Outlier weighting.

■ Weighting:

☐ You could adjust parameters by referring to the Difference Map results.

☐ The higher value of the Difference Map, the higher probability of the edge.

Simple mode:

☐ Weight level: provide three style curves

☐ Level 0~2: Smoothness is from weak to strong.

Advance mode:

☐ You can fill in the parameter values with the corresponding interval based on the value of the Difference Map result.

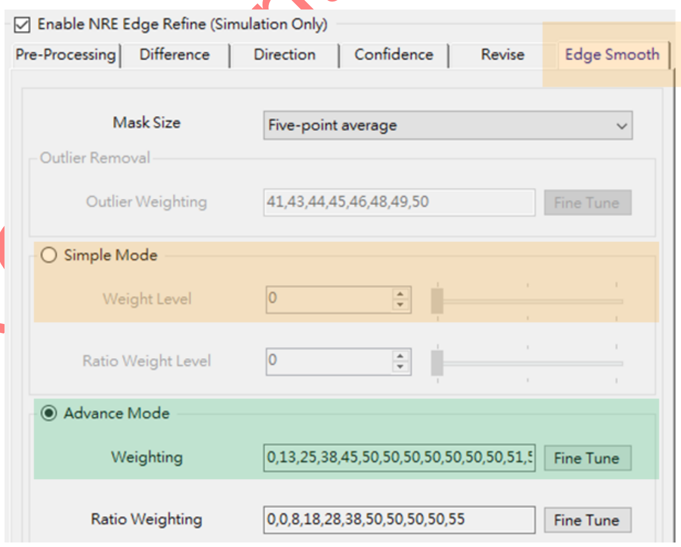


Fig. 5-118 Parameter Location for Weighting

■ Ratio weighting:

☐ You could adjust parameters by referring to the Confidence Map results.

☐ The higher value of the Confidence Map, the higher the confidence level in that direction.

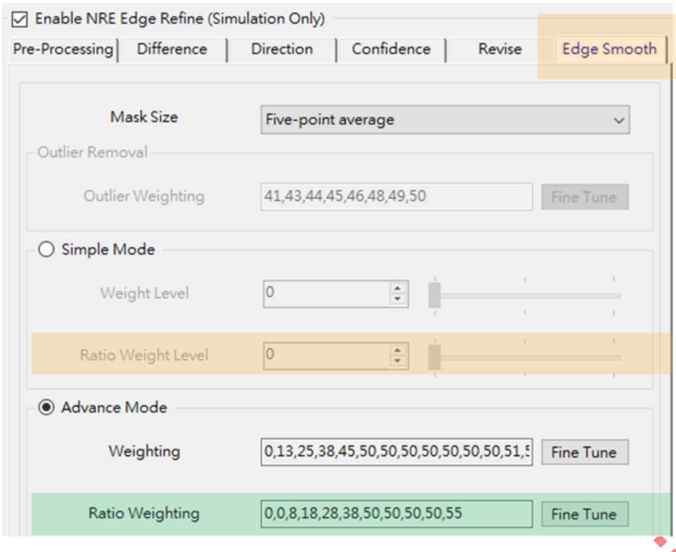
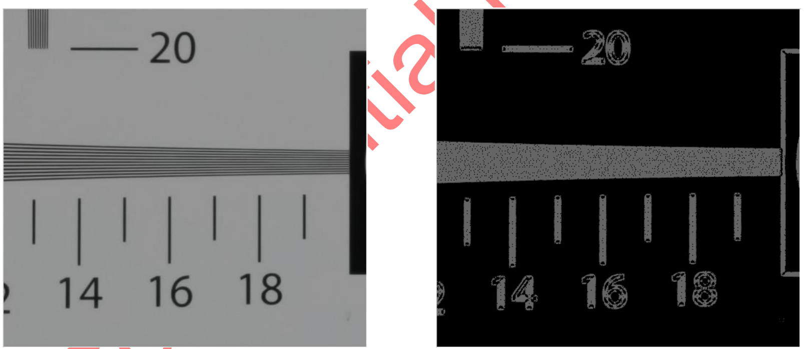


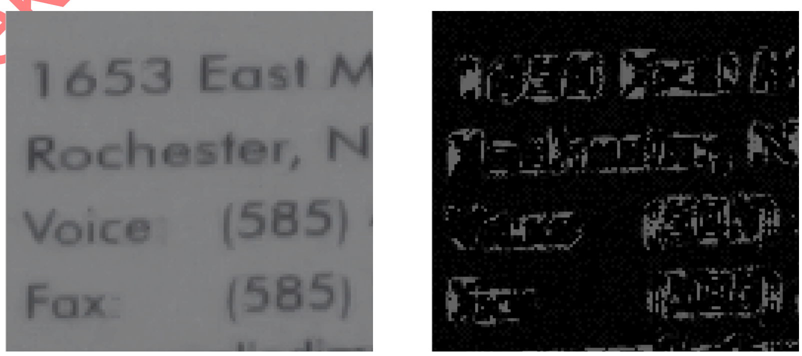
Fig. 5-119 Parameter Location for Ratio Weighting

- ■ Overall check parameters:
- □ The sum of these three weights (outlier weighting, weighting, ratio weighting) is the final total weighting, which will affect the final smoothness.
- □ If the value of the weighting map is higher, it means that the smoothing will be stronger. As shown below.



(a) Original image (b) Total weight map

Fig. 5-120 Total weight map at hard edge area



(a) Original image (b) Total weight map

Fig. 5-121 Total weight map at text part.

5.11.8. The tuning steps for example:

- **Step1:**

First, we observe the noise level of the original image and determine the expected smooth level.

- ☐ Low ISO: The level of smooth could be weaker.
- ☐ High ISO: The level of smooth could be stronger.

(a) 10lux_2700k (b) 250lux_2700k

Fig. 5-122 Two different noise levels.

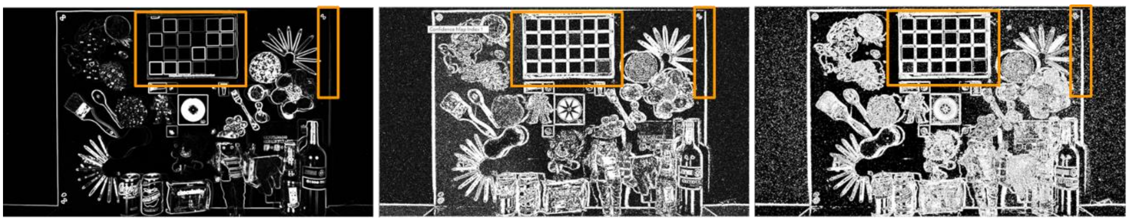
- **Step2:**

Choose debug information, ***Total Weight Map***. And observe the results of the current parameters and review the areas where need to be strengthened or weakened. As shown in Fig. 5-123.

Fig. 5-123 Total weight map result

- **Step3:**

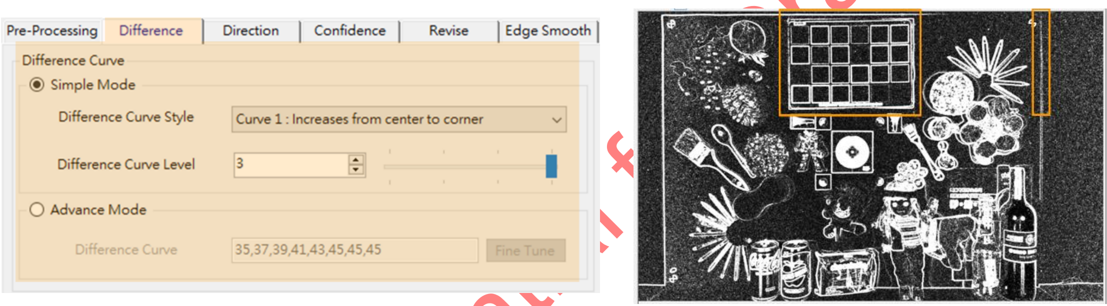
Besides, also need to observe others debug information, there are respectively, ***Difference Map, Confidence Map, Revise Map***. Find out which part causes the detection strength not as strong in the ***Total Weight Map***. In the above case, we could find the detection intensity of the ***Difference Map*** is weaker than others. (As shown in Fig. 5-124)



(a) Difference Map (b) Confidence Map (c) Revise Map

Fig. 5-124 Three debug information ·

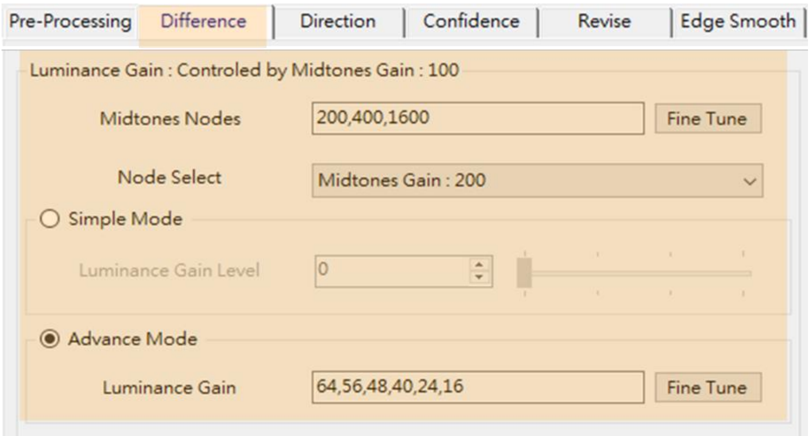
- **Step4:**
- So, we select the ***Difference Map***, and observe whether the edge is detected or not. Usually the edge is not effectively detected, which might some characteristics, such as at dark position or the broken edge.
- Select the Simple Mode, and observe the changes in the ***Difference Map***. In general, the overall detection intensity can be increased, and the corner of the image can be a little stronger than the center. The fine-tune results as shown in Fig. 5-125 (b).



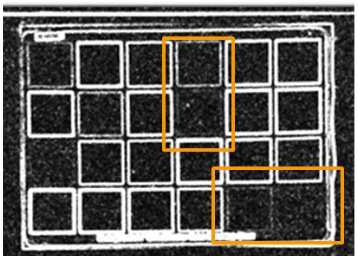
(a) Parameter Location for Difference Curve (b) Difference map result

Fig. 5-125 Select the Simple Mode, and observe the changes in the Difference Map

- **Step5:**
- If the dark area still cannot be detected effectively. We could improve this problem by adjusting the Luminance Gain Curve, but it will also result in noise being easily detected. As shown in Fig. 5-126. You can use simple mode to quickly try and make it fit the expectation or not.
- Generally, it is not recommended to use this method, because the value of this parameter is determined automatically by midtones.

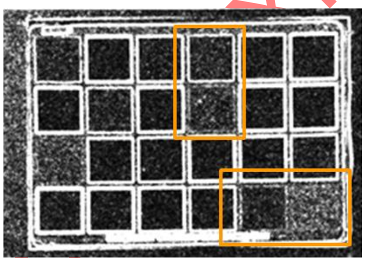


(a) Parameter Location for Luminance Gain



(b) The area is where we want to be enhanced

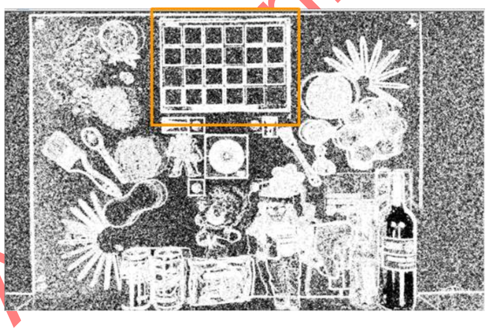
(c) Compare with original input image.



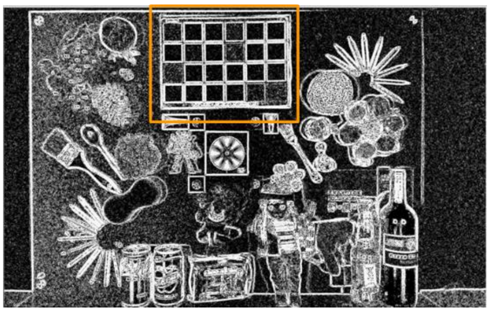
(d) After tuning

Fig. 5-126 How to adjusting the Luminance Gain Curve.

- **Step6:**
  - Then, check the result of the ***Revise Map***. If you want to have a stronger smoothing effect, please make sure the most of the edges are detected.
  - In addition, you also need to check the total weight map to ensure that it is as expected. For other flat areas, it doesn't matter if they're wiped at high ISO because the NRE also will smooth them. As shown in Fig. 5-127.



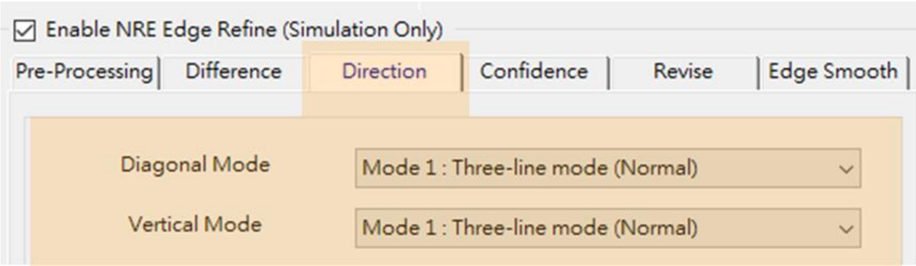
(a) The area is where we want to be enhanced.



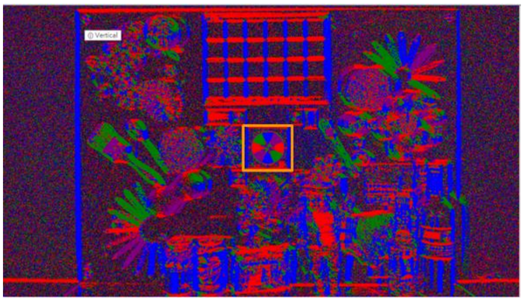
(b) Compare with original input image.

Fig. 5-127 Check the result of the Revise Map

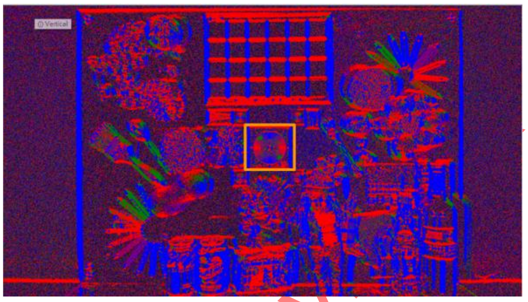
- **Step7:**
  - Check the Direction Map to make sure that the direction of the edge you want to smooth is detected. As shown in Fig. 5-128.
  - **Please note**: If a position didn't be defined direction, it would be not smoothed at all. Besides, our common setting is Mode 1 (Three-line mode, normal).



(a) Parameter Location for Direction



(b) Diagonal, Vertical: Mode1



(c) Diagonal, Vertical: Mode2

Fig. 5-128 Check the Direction Map

5.12. LTM

LTM (Local Tone Mapping) applies tone mapping gain to each pixel depending on the local brightness to enhance visibility. There are two stage, statistics stage and estimation stage.

In the statistics stage, get pseudo Y value from LTM estimation stage. And save stats data which will be used in the next frame estimation stage.

In the estimation stage, estimate LTM Gain after NRE, and apply LTM Gain on RGB Sep image which is converted from YCC420 Sep. The final output is 12 bits RGB Sep image.

5.12.1. LTM Statistics

- LTM stats is used to calculate local average mean map.
- Collect Y into spatial and intensity grids.
- Apply bilateral filter to the grids to weighting average.

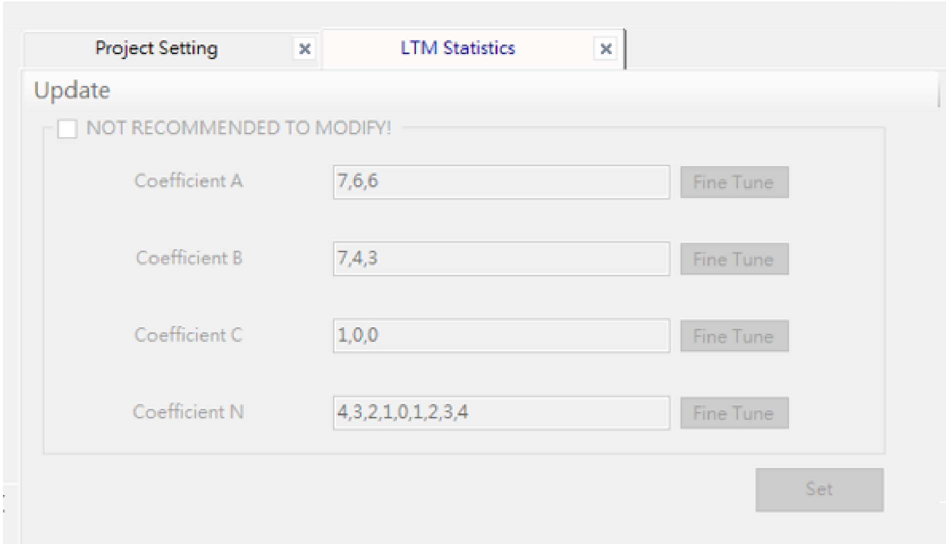


Fig. 5-129 The interface of LTM statistics tuning

- Bilateral filter coefficients
  - Coefficient A~C: To create the spatial domain 3x3 filter coefficients. It's recommended not to modify.
  - Range:A、B: 0~7; C: 0~1
  - formula
    - F0 = $2^{a0} + 2^{b0} - c0$
    - if a0 = b0 = c0 = 0, F0=0.
    - F1 = $2^{a1} + 2^{b1} - c1$
    - if a1 = b1 = c1 = 0, F1=0.
    - F2 = $2^{a2} + 2^{b2} - c2$
    - if a2 = b2 = c2 = 0, F2=0.
  - Increase the outer coefficients, make the center grid stats more average with outer grid stats.

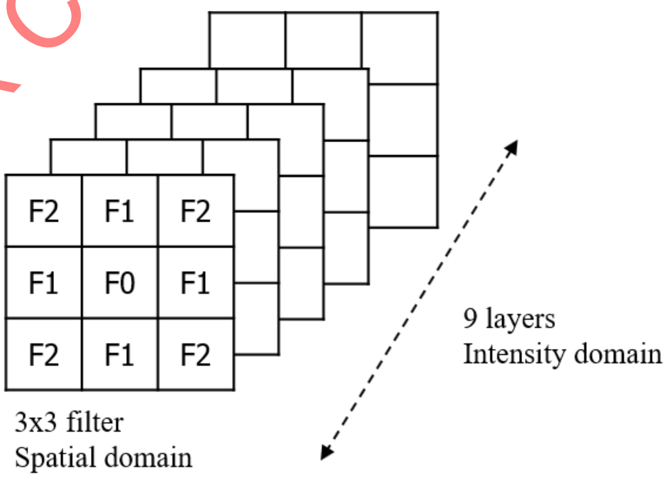


Fig. 5-130 filter coefficients layout

- Bilateral filter coefficients

- Coefficient N
  - The bits shift value to each intensity layers, which is as the weighting of each layers.
  - It's recommended not to modify
  - Range:0~15
  - Increase the value, less weighting on the intensity layer.
  - If the values are the same in the outer layer and center layer, smoother to the grid stats. But may cause halo in the LTM result.

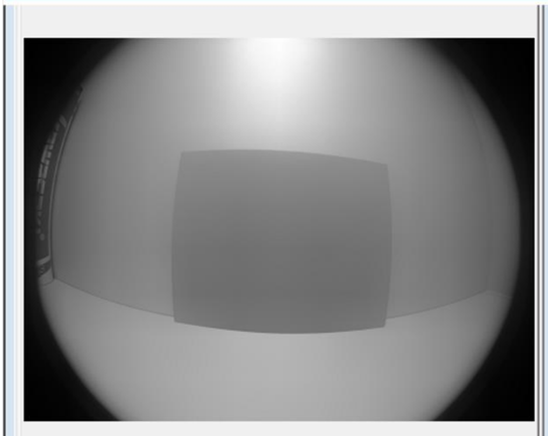
Local Y with default stats coefficients	Local Y with average stats coefficients
	

Fig. 5-131 local average mean map with different filter coefficients.

5.12.2. LTM Estimation

- First, convert YCC420s to RGBs before apply LTM.
- LTM applies local tone mapping gain to each pixel depending on the local brightness to enhance visibility. Include
  - Local Brightness Enhancement
  - Local Contrast Enhancement
- If the midtone and shadows gain are around 1.0x, use the User defined LTM curve and scale table in this block.
- After apply LTM gain, output is 12bits RGBs.
- And then, apply inverse inner gamma on 12bits RGBs. The final output is still 12bits RGBs.

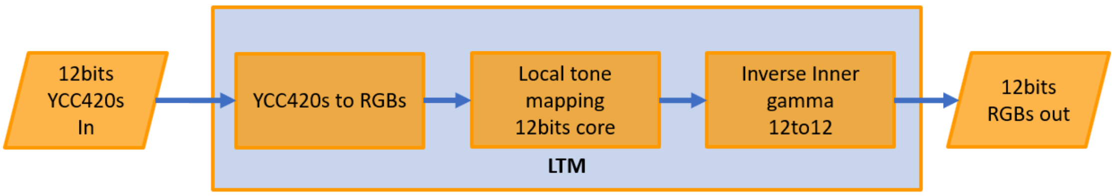


Fig. 5-132 The flow of LTM

5.12.2.1. Tool Bar UI

Please refer to Fig. 5.106, when you load a RAW image, there is a tool bar in LTM,

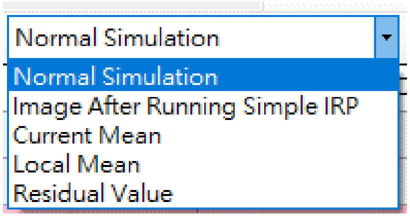


Fig. 5-133 UI of Preview Option

- Preview Type
  - Normal Simulation:
    - show preview as LTM result.
  - Image After Running Simple IRP:
    - show preview as LTM result + IRP S2.
  - Current Mean:
    - Current mean(=Y) is the Y mean of the ltm input image.
    - show preview as Y mean image, which is used to estimate LTM.
    - Move cursor on the preview, get Current Mean Index for tuning user defined LTM Curve. (Fig. 5-134)
  - Local Mean:
    - Local mean(=L) is the local average Y mean.
    - show preview as Local Y mean image, which is used to estimate LTM.
    - Move cursor on the preview, get Local Mean Index for tuning user defined Scale Curve. (Fig. 5-134)
  - Residual Value:
    - show preview as Residual Value.
    - Residual Value = (Y-L)*c0*c1
    - c0 is the boost gain LUT from Brighter/Darker Enhance Curve.
    - c1 is the boost gain from Brighter/Darker Strength.
    - Move cursor on the preview, get Local Enhance Index for tuning Local Brighter/Darker Enhance (Local Contrast Enhance).
    - If Residual Value <0, tune the Darker Enhance Curve. Otherwise, tune Brighter Enhance Curve. (Fig. 5-134)

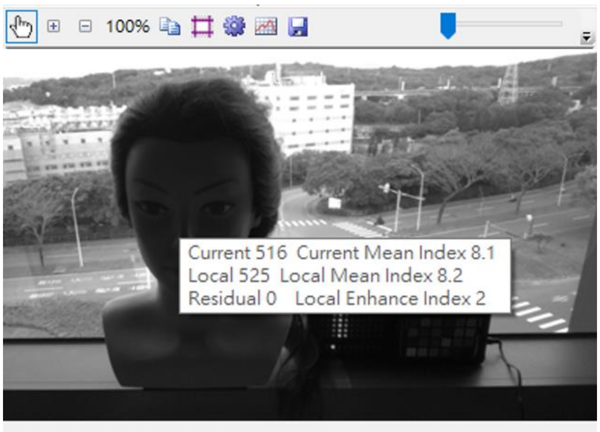


Fig. 5-134 Tuning Info from Preview

5.12.2.2. The Order of Tuning

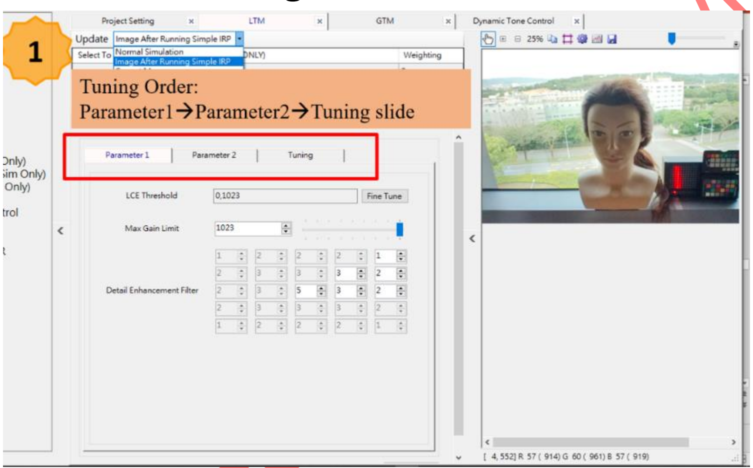


Fig. 5-135 The LTM Interface

There are three slides to tune. The Tuning order is Parameter1→Parameter2→Tuning slide.

5.12.2.3. Parameter1

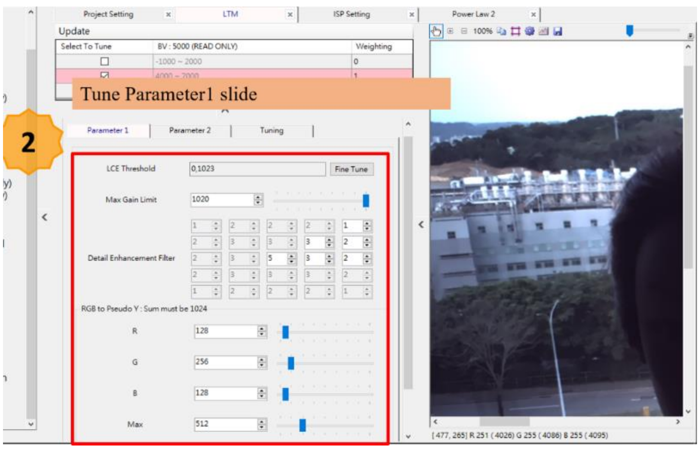


Fig. 5-136 The Parameter1 Interface

- LCE Threshold
  - the min and max clamp of residual value.
  - Range: 0~4095
- Max Gain Limitation
  - The max limitation of LTM gain boost.
  - Range: 0~1023
- Detail Enhancement Filter
  - The coefficient of 5x5 gaussian filter, to enhance local detail.
  - Range: 0~7
  - Recommend the Default = (5,3,3,2,2,1)
  - The coefficients are smoother, like average filter, more detail enhanced. But may cause halo effect around the texture edge. (Fig. 5-137)
- RGBs to pseudo Y
  - Before LTM core, calculate pseudo Y to estimate and LUT.
  - Finetune c1~c4, the coefficients of R,G,B and max(R,G,B).
  - Range:0~2047
  - RGB to Pseudo Y coefficients, sum must be 1024.
  - Pseudo Y =(R*c1+ G*c2+B*c3+max(R,G,B)*c4)>>10;
  - Default = (128,256,125,512)

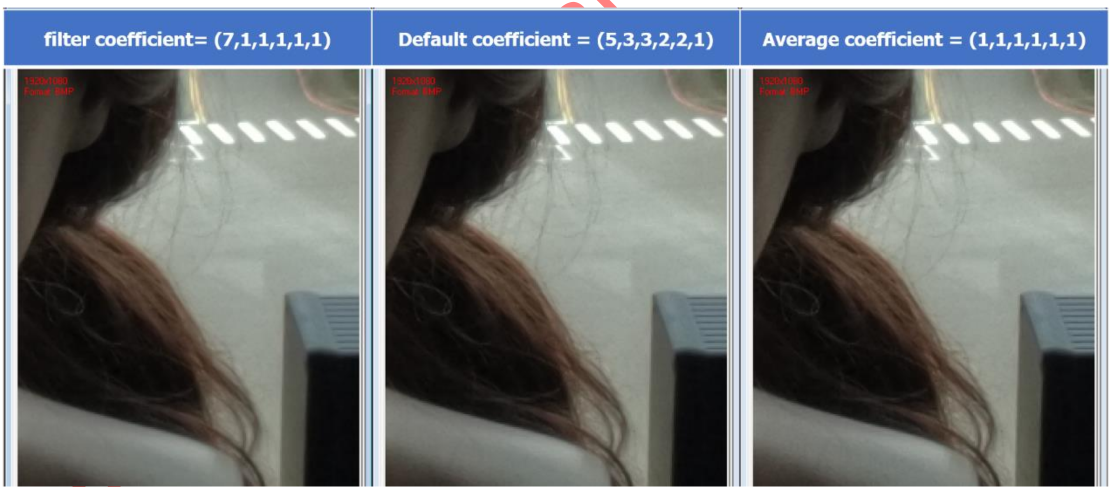


Fig. 5-137 The diff of detail enhancement filter coefficients

5.12.2.4. Parameter2

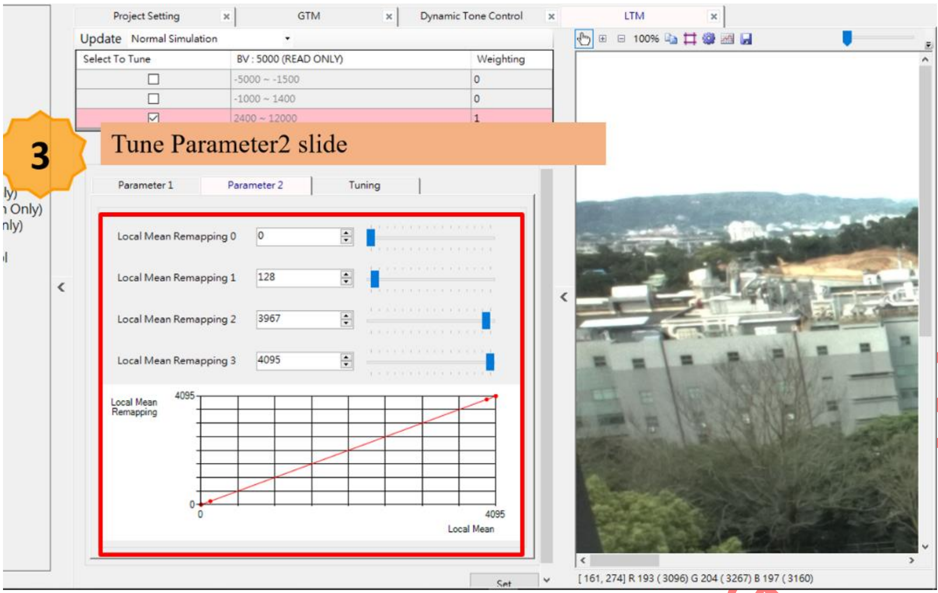


Fig. 5-138 The Parameter2 Interface

■ Local Mean Remapping 0~3
- ☐ tune the four points to control tone curve for Local Mean re-mapping.
- ☐ Range: 0~4095
- ☐ Default: (0,128,3967,4095)
- ☐ Decreasing the curve of dark key to boost brightness in the dark area.
- ☐ Increasing the curve of high key to suppress brightness in the bright area.
- ☐ The distance should be larger to make tone smooth changing between P0~P1 and P2~P3.

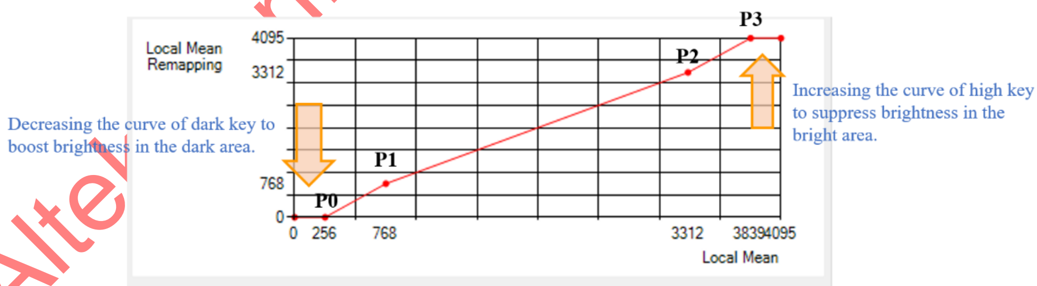
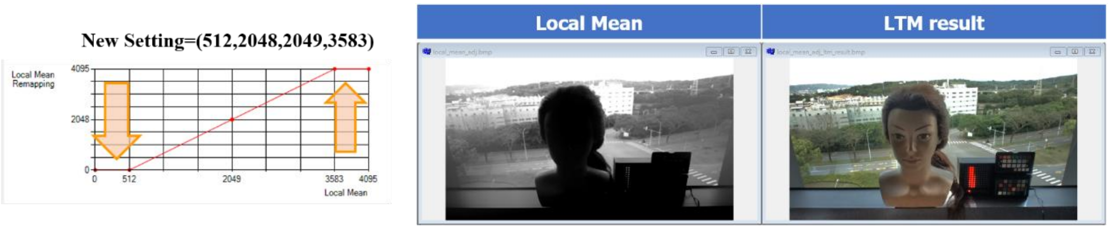


Fig. 5-139 local mean remapping curve

Fig. 5-140 LTM result with default local mean remapping setting



Decreasing the curve of dark key to boost brightness in the dark area.
Increasing the curve of high key to suppress brightness in the bright area.

Fig. 5-141 LTM result with new local mean remapping setting

5.12.2.5. Local Brightness Tuning

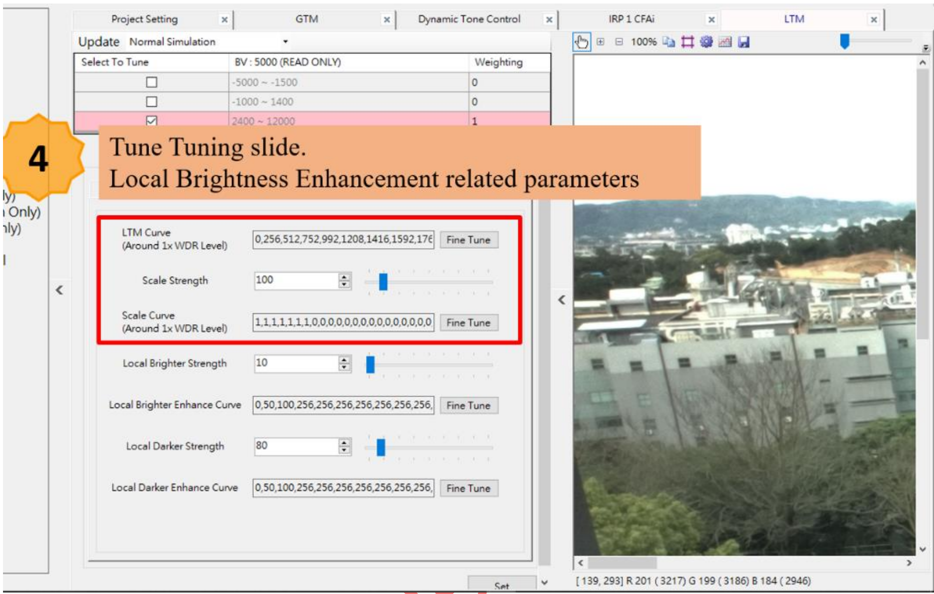


Fig. 5-142 Local Brightness Enhancement Interface

- Local Brightness Enhancement related parameters:
  - ☐ LTM Curve
    - The User Defined brightness increment (= ΔY(Y)) of each Current Mean Index.
    - Range: 0~65535
    - Effective conditions:
      - ☐ midtone gain and shadows gain are around 1.0x.
    - Increasing these parameters according to the Current Mean Index, make image brighter. (Fig. 5-143)
    - curve should be smooth to avoid brightness inversion
  - ☐ Scale Curve
    - The User Defined Brightness Boost Gain (= gain1(L)) of each Local Mean Index.
    - Range: 0(0.0x) ~32767(31.99x)
    - Effective conditions:
      - ☐ midtone gain and shadows gain are around 1.0x.
    - Increasing these parameters according to the Local Mean Index,

make image brighter. (Fig. 5-144)

- curve should be smooth to avoid brightness inversion

- Scale Strength
  - Increasing strength (= gain2), enhance local brightness (Fig. 5-145).
  - Range: 0(0.0x) ~800(8.0x)
  - Default = 100(1.0x)

- Local Brightness Enhancement = Y+ ΔY(Y)*gain1(L)*gain2

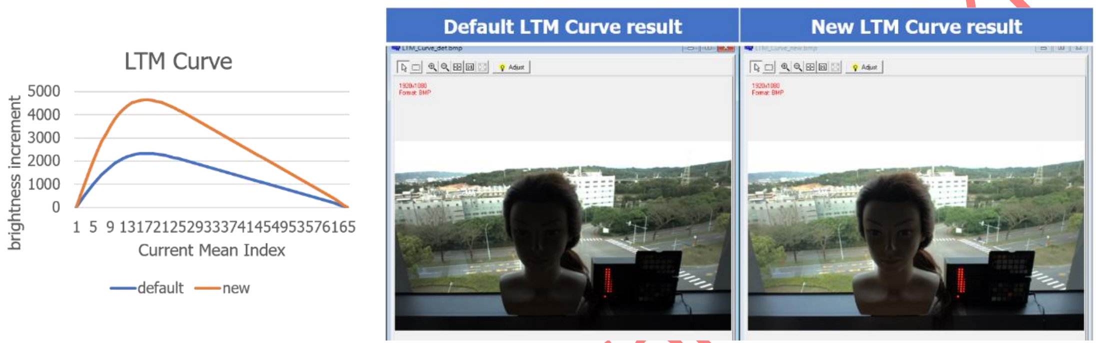


Fig. 5-143 LTM result with difference LTM Curve

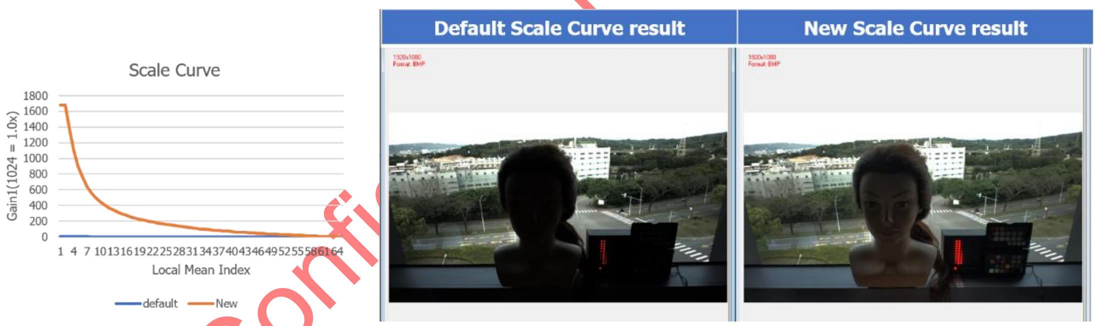


Fig. 5-144 LTM result with difference Scale Curve

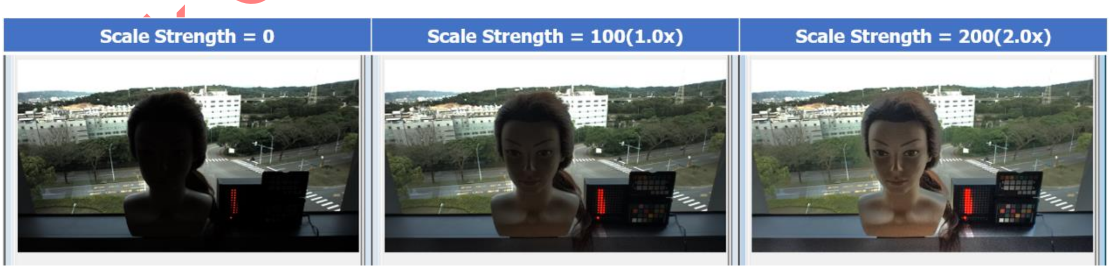


Fig. 5-145 LTM result with difference Scale Strength

5.12.2.6. Local Contrast Tuning

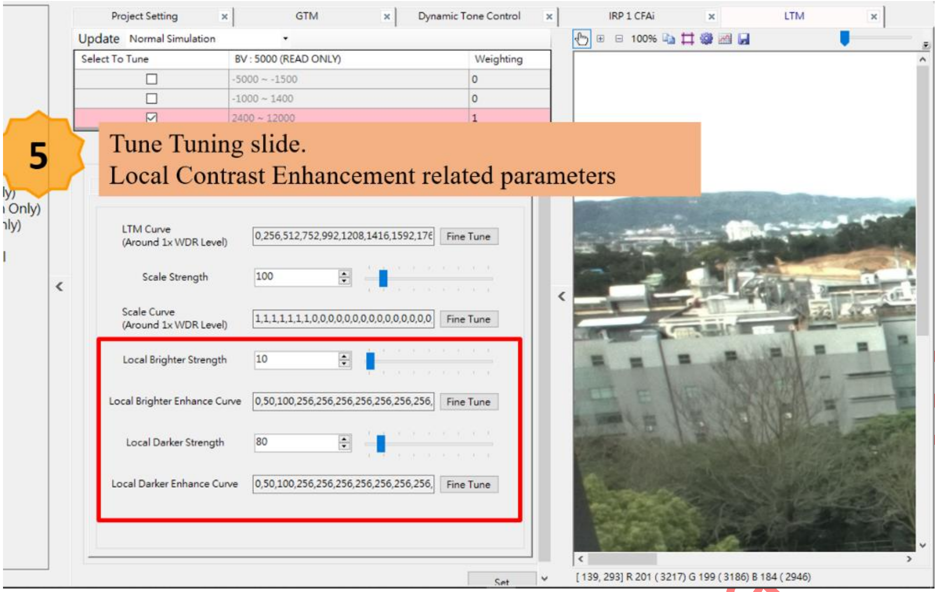
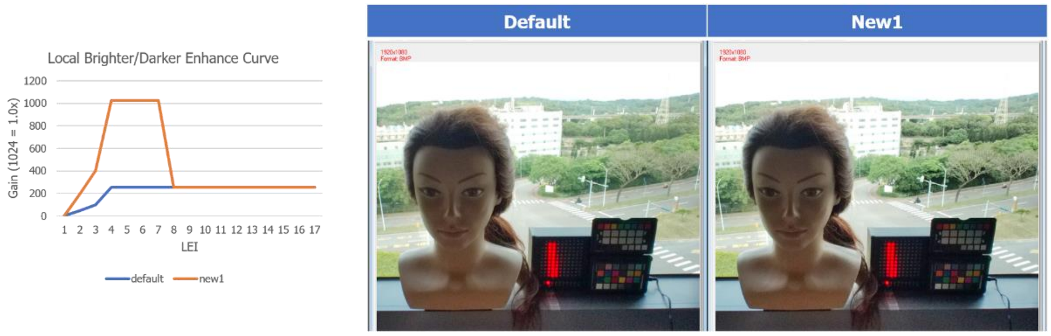


Fig. 5-146 Contrast Enhancement Interface

- Local Contrast Enhancement related parameters:
  - Local Brighter/Darker Enhance Curve
    - tune the gain value in this curve according to the Local Enhance Index (LEI)
    - Range:0(0x) ~65535(63.99x)
    - Increase enhancement gain to make local bright/dark area brighter/darker, to enhance local contrast. (Fig. 5-147)
  - Local Brighter/Darker Strength
    - The strength to make local bright/dark area brighter/darker, to enhance local contrast. (Fig. 5-148)
  - Suggest to lower the gain of the first or second LEI in the enhance curve.
    - Avoid to enhance noise in the dark area.
- Local Contrast Enhancement = (Y-L) *c0(LEI)*c1
  - Residual Value = (Y-L) *c0(LEI)*c1
  - Current mean(=Y) is the Y mean of the ltm input image.
  - Local mean(=L) is the local average Y mean.
  - C0(LEI) is the boost gain from Brighter/Darker Enhance Curve according to Local Enhance Index (LEI).
  - c1 is the boost gain from Brighter/Darker Strength.
  - If Residual Value <0, tune the Darker Enhance Curve. Otherwise, tune Brighter Enhance Curve.



Enhance Local Contrast in the low to middle key.

Fig. 5-147 Local Brighter/Darker Enhance Curve

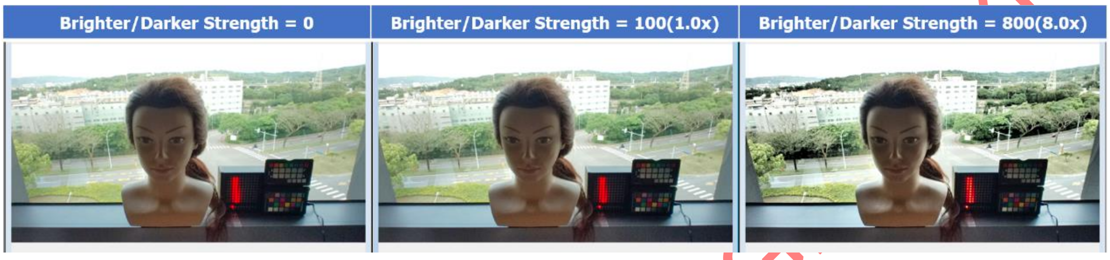


Fig. 5-148 Different Brighter/Darker Strength

5.13. HWIRP Stage 2

5.13.1. CCM

CCM is applied to map the characteristic of color from sensor to human eye.

- **Notice : Light source condition**
  - ☐ High color temperature, like D65 (6500K± 200K) @ above 320 lux
  - ☐ Middle color temperature, like CWF or TL84 (4000K± 200K) @ above 320 lux
  - ☐ Low color temperature, like incandescent (2700K± 200K) @ above 320 lux

CCM Main Page Interface Introduction:

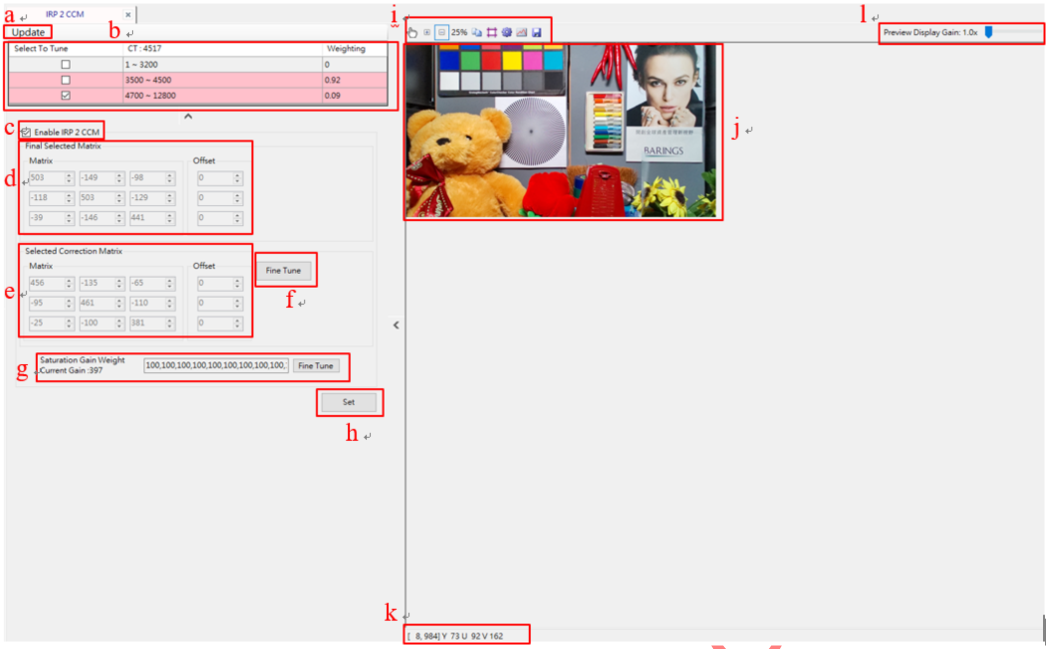


Fig. 5-149

(a) Update button

Click "Update" and the CCM parameter will be updated to tuning tool main form.

(b) CT (color temperature) interpolation table

CCM is divided into five groups according to the color temperature, different color temperatures use the same matrix or matrix which linear interpolation of two color temperatures.

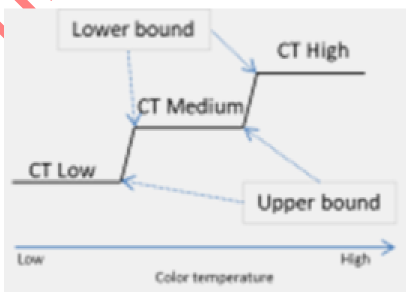
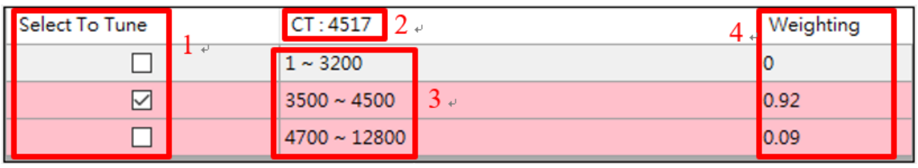


Fig. 5-150



Select To Tune 1	CT : 4517 2	4 Weighting
☐	1 ~ 3200	0
☑	3500 ~ 4500 3	0.92
☐	4700 ~ 12800	0.09

Fig. 5-151

1. Select To Tune

Select the CT region to tune CCM.

2. Current CT(color temperature)
   Show the color temperature of the current simulation.
3. CT region setting
   The CT region can be set according to needs. Usually divided into three color temperatures: high, medium and low. See CCM Notice.
   The adjustment method is to directly modify the CT number, then push the keyboard's ENTER. After push the "Update" button, setting will be done.
4. Weighting
   Show the weighting to use when linearly interpolating at current simulation.

The example shown above: the current CT is 4517K, so the final CCM use the linear interpolation of the second matrix and the third matrix. The weighting of the second and the third matrix are 0.92 and 0.09. The second and the third region change to red background when the weighting don't equal to zero. So we can tune the second matrix and the third matrix at this case.

(c) Enable IRP2 CCM
Use the CCM parameter (on) or identity matrix (off).

(d) Final Selected matrix
Show the final CCM of the current simulation.

(e) Selected correction matrix
Show the selected matrix according to selected CT region (see [(b) CT interpolation table]).

(f) Selected correction matrix (Fine Tune), see **CCM Fine Tune Interface Introduction**
Click "Fine Tune" to fine tune selected matrix.

(g) Saturation Gain Weight (Fine Tune)
Fine tune the gain-weight table to adjust saturation weighting according to gain.

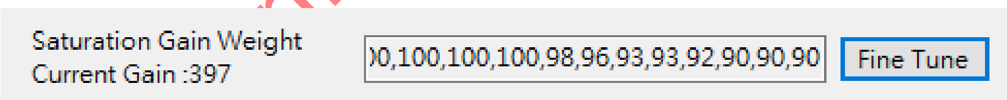


Fig. 5-152

1. Current Gain means sensor gain * digital gain * midtones gain * shadow gain (See page ISP setting -> Condition)
2. The value of table means weighting, example: 100 means 100%

(h) Set button
Click "Set" to apply parameter to (j) simulation result.

(i) Image toolbar
   A1. Move Image
      Move the simulation image.
   A2. Zoom In Image
      Zoom in the simulation image.
   A3. Zoom Out Image
      Zoom out the simulation image.

A4. Compare Image

Push button and show the simulation image by last updated parameter.

A5. Selection

Click to select regions of interest for analysis.

A6. Setting

Choose selection type for A5.

A7. Data analysis

Data analysis for selected regions of A5.

A8. Save Bitmap

Save simulation image.

(j) Simulation results

Display current simulation result.

(k) Mouse information

Show related information on mouse pointer.

(l) Preview Display Gain

Adjusts the gain of the simulation display.

CCM Fine Tune Interface Introduction:

At fine tune interface, we can choose a target to approach or fine tune matrix directly.

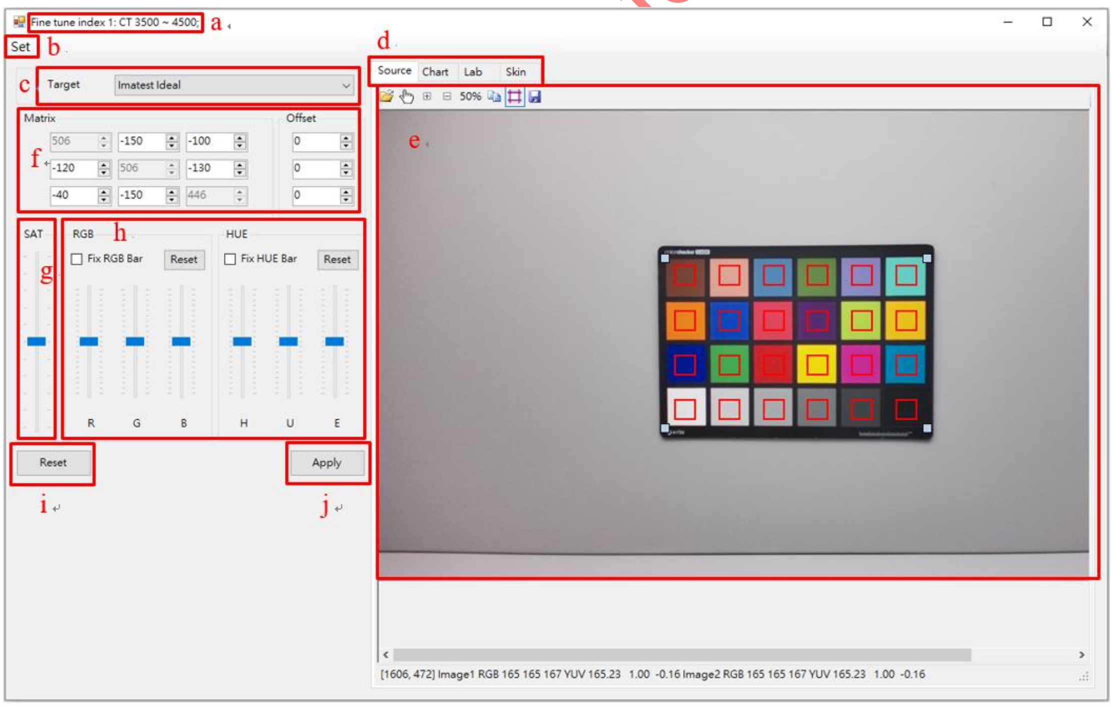


Fig. 5-153

(a) Fine tune index

Show the selected CT region of CCM main page. The fine tune page only adjusts parameters of selected region.

(b) Set button

Click to update the parameters to CCM main page.

(c) Target

At fine tune page, we can optimize CCM by approaching a selected target.

Imatest Ideal

- Imatest Ideal
- Color Checker Spec
- A1 5000K
- A1 2800K
- Manual

Fig. 5-154

There are several target to choose currently. The "Manual" type could choose any target to approach. There will be examples later.

(d) Analysis toolbar

1. Source

   Load a raw image with 24 color checker to analysis.

2. Chart

   Details of the source (final simulation) and target.

   User can adjust the weight of optimization algorithm.

Source | Chart | Lab | Skin

Delta_C (Weighted Avg 4.090 Max 16.250) Delta_E (Weighted Avg 5.515 Max 16.673)

	Weight	Source	R	G	B	Target	R	G	B	Delta C	Delta E
☑	1		105	68	54		113.985	80.835	67.575	2.650	5.440
☑	1		209	165	153		194.820	147.900	127.755	5.113	8.046
☑	1		115	145	178		92.820	122.400	156.060	0.746	8.639
☑	1		97	126	75		90.525	107.610	64.515	6.366	8.995
☑	1		150	149	190		129.285	128.010	176.205	4.745	9.089
☑	1		137	201	193		97.410	190.995	170.850	11.543	12.692
☑	1		212	126	58		221.085	122.655	47.685	7.312	7.325
☑	1		82	107	185		70.635	90.780	170.340	3.100	6.766
☑	1		206	92	104		193.290	82.110	97.410	2.039	4.423
☑	1		88	61	104		92.055	57.375	106.335	4.908	4.918
☑	1		171	199	78		160.395	189.210	61.710	2.808	4.602
☑	1		215	181	49		228.225	160.650	41.310	16.250	16.673
☑	5		39	55	134		39.525	62.730	146.880	2.675	4.234
☑	5		76	153	74		70.635	149.940	72.675	0.960	1.546
☑	5		183	51	57		173.655	50.745	56.865	3.842	4.236
☑	1		221	205	37		236.640	198.135	19.635	10.512	10.520
☑	1		187	84	152		188.190	83.895	151.470	0.633	0.648
☑	1		43	134	171		0.000	137.700	168.300	6.577	6.593
☑	0		224	223	222		244.800	245.310	242.250	1.073	7.738
☑	0		202	202	202		200.430	202.215	202.215	0.668	0.671
☑	0		169	169	169		160.905	162.945	163.200	0.775	2.542
☑	0		120	121	121		120.870	121.125	121.635	0.254	0.281
☑	0		67	67	68		82.620	84.150	85.680	0.865	7.173
☑	0		33	33	33		48.705	49.470	50.745	0.783	7.731

Max Count of Over-Saturated: 0

Cost Ratio from Mean to Max (0 : All Mean; 1.0 : All Max): 0.00

Optimize

Fig. 5-155

3. Lab

   Show the distribution of the Current (source before approach), Tuning (source after approach), and Target at CIELab color space.

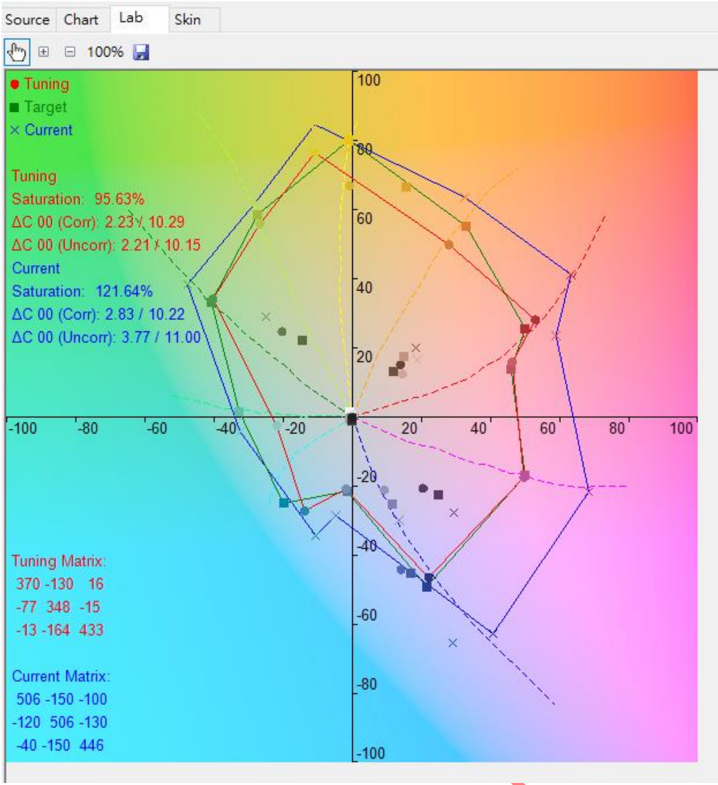


Fig. 5-156

4. Skin

Show the skin distribution of the Current (source before approach), Tuning (source after approach), and Target at part of the CIELab color space.

Fig. 5-157

(e) Display window

Show the simulation result or analysis result.

(f) Matrix

The color correction matrix of the selected CT region. It will be adjusting after optimization. Or we can adjust the matrix directly.

(g) SAT

Adjust saturation manually.

(h) RGB/HUE

Adjust RGB/HUE manually.

(i) Reset button

Click to reset the parameter from CCM main page.

(j) Apply button

Click to apply parameters of the (f) Matrix to (e) display window.

Saturation Gain Weight Interface Introduction:

Adjust saturation weighting according to gain (sensor gain * digital gain * midtones gain * shadow gain).

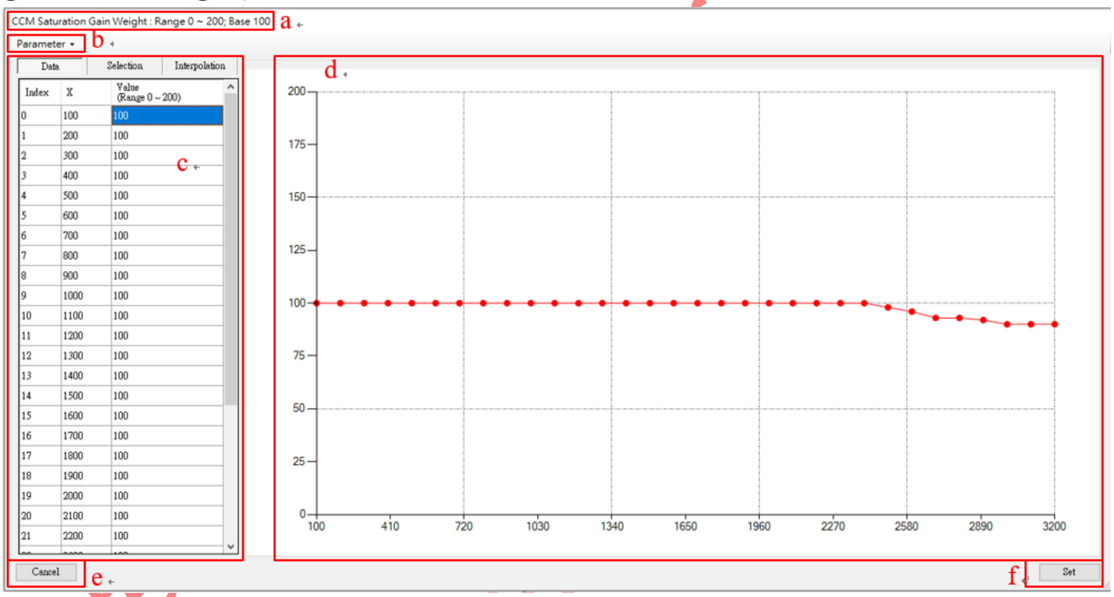


Fig. 5-158

(a) Weighting range and gain base

1. The weighting range are between 0 to 200. The value means weighting, example: 100 means 100%.
2. Gain base is 100. 100 means 1x gain.

(b) Parameter

Save or load the weighting table.

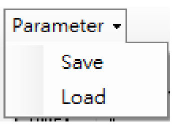


Fig. 5-159

(c) Weighting edition table

1. Data

   User could edit value directly.

   Index: The label of the data on the table.

   X: Gain base 100 (100 means 1x gain)

   Value: Weighting, range (0~200) (100 means 100%)

2. Selection

   User can adjust value with range of x once at a time.

Fig. 5-160

3. Interpolation

   Linearly interpolate “range” with the range of “x”.

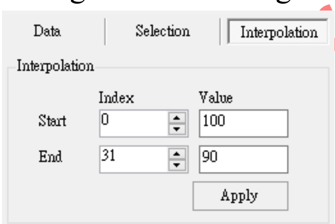


Fig. 5-161

(d) Weighting edition figure

x-axis: gain

y-axis: value

User could adjust the point directly.

Selection also be applied here.

(e) Cancel button

Cancel the page without saving.

(f) Set button

Update the parameters of this page to the CCM main page.

The process to tune CCM:

1. Check LSC calibration, LSC tuning, AWB tuning completed.
2. Load raw image and set condition on ISP Setting page.

   Finally, push Update button.

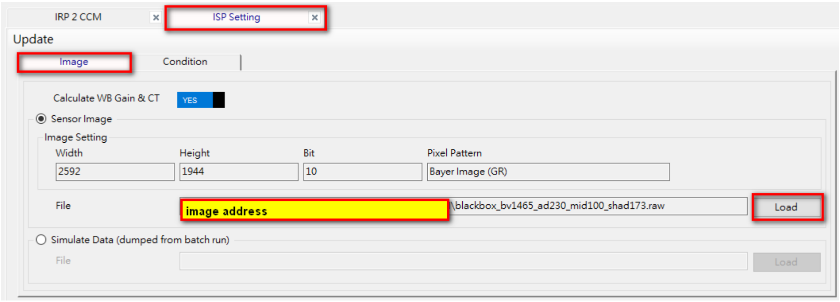


Fig. 5-162

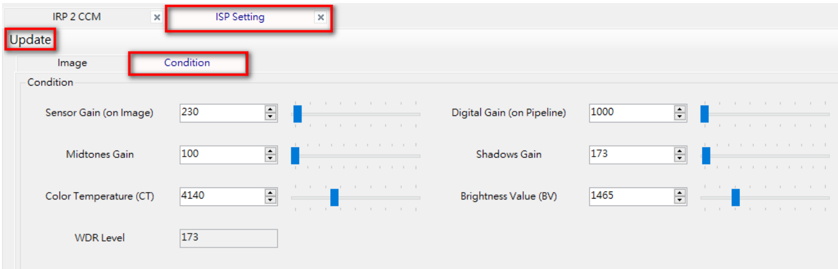


Fig. 5-163

3. Select the corresponding CT area to adjust the parameters on CCM main page. Push the Fine Tune button to switch to the fine tune page.

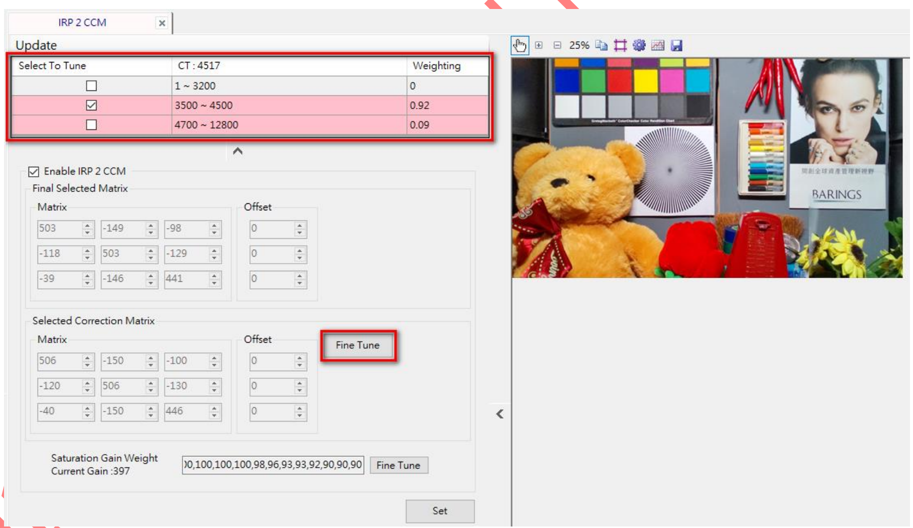


Fig. 5-164

4. Matrix tuning with manual mode or optimize mode

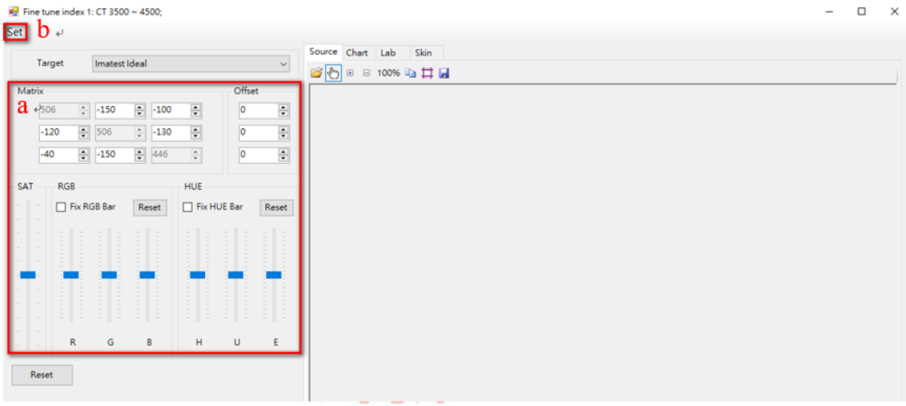


Fig. 5-165

Manual mode:

(a) Users can set matrix or adjust saturation or RGB/HUE manually.

(b) Click "Set", the parameters will be updated to CCM main page.

5. Check tuning result

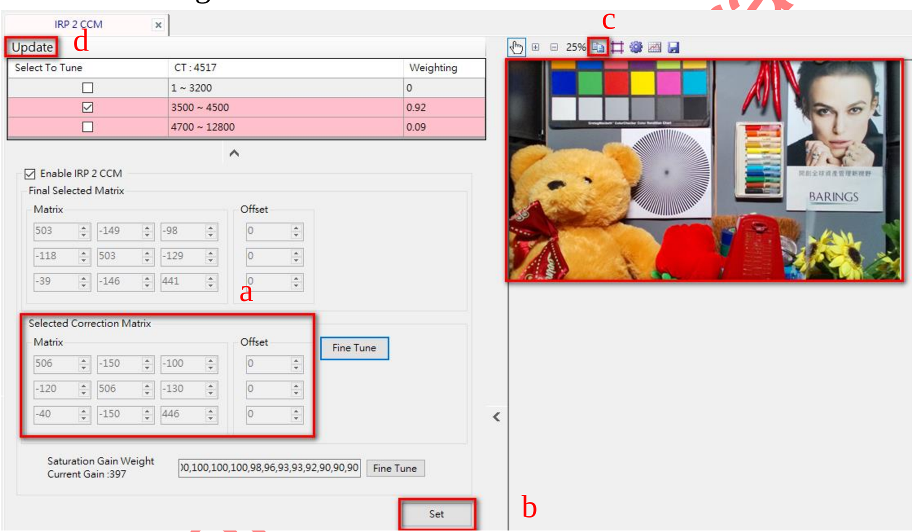


Fig. 5-166

(a) Check if the parameters here have been updated.

(b) Click "Set", run simulation with new parameters.

(c) The simulation result will display on window. User can compare new parameters and parameters of tuning tool main page by image toolbar.

(d) If tuning complete, click "Update" to update the new parameters to tuning tool main page.

The example of optimize mode:

This example will show how to choose a target to optimize CCM.

1. Load color chart raw image. (Note: The CT of the raw image must be in the selected range) Lower sensor adgain is recommended.

2. Select the color patch of source image.

   After loading image, the color of image may be a bit strange. But it's okay. This is because when loading images here, tuning tool doesn't know what the color temperature is. So, the default WB gain is set from the CCM main form. When users choose target (next step), source will be applied with the same WB GAIN as target. Under the same WB standard, the next will optimize a set of CCM to approach target.

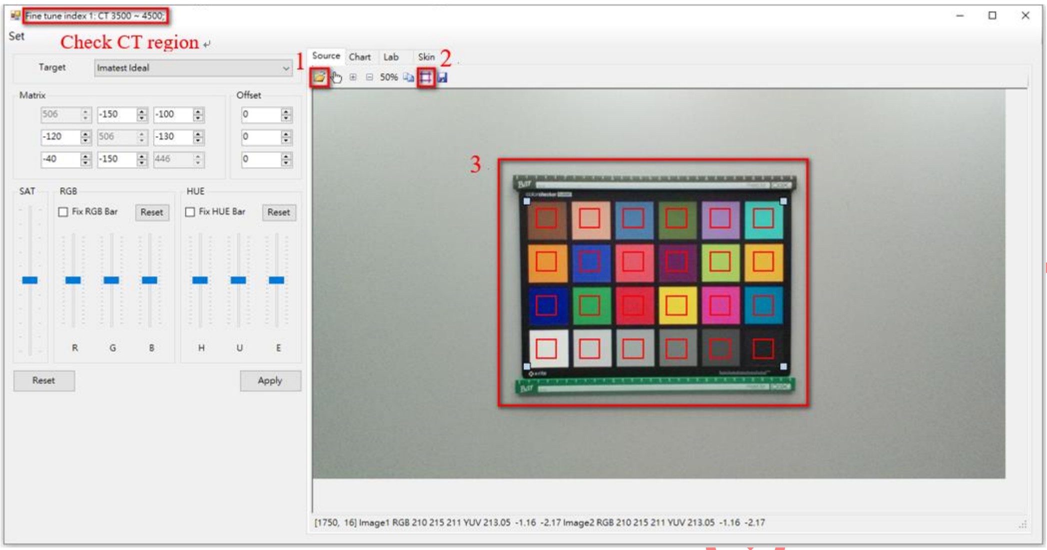


Fig. 5-167

3. Select the target type. We choose “Manual” in this example. This type can choose any target to optimize CCM.

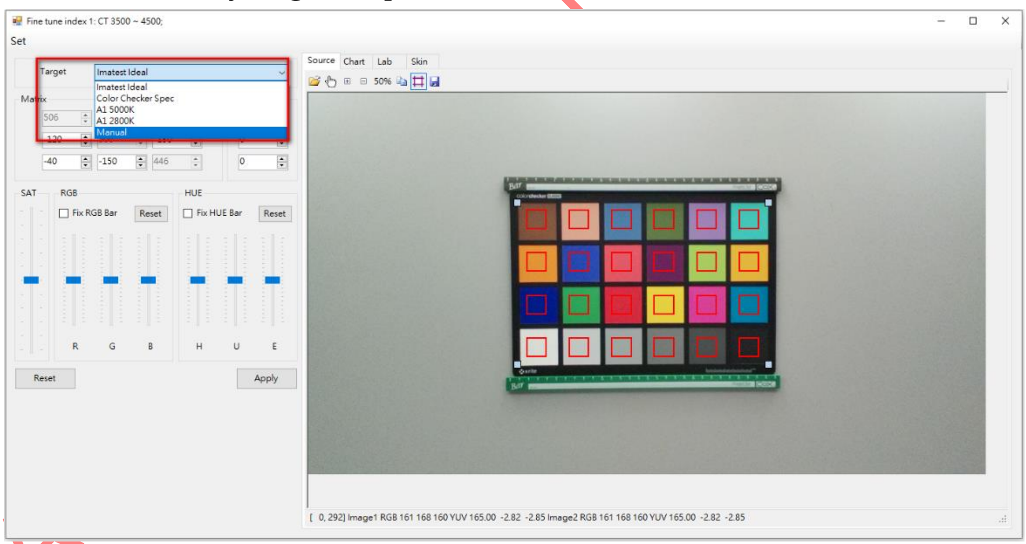


Fig. 5-168

4. After choose “Manual” type, the target page will appear to the right of source page (only for “Manual” type). Load target image (jpg or bitmap), and select the color patch again. Note that for better estimation result, the G mean on patch 22 between source image and target image should not have large difference (15%). Otherwise, tuning tool will show some warning message to notify user to confirm chart image first.

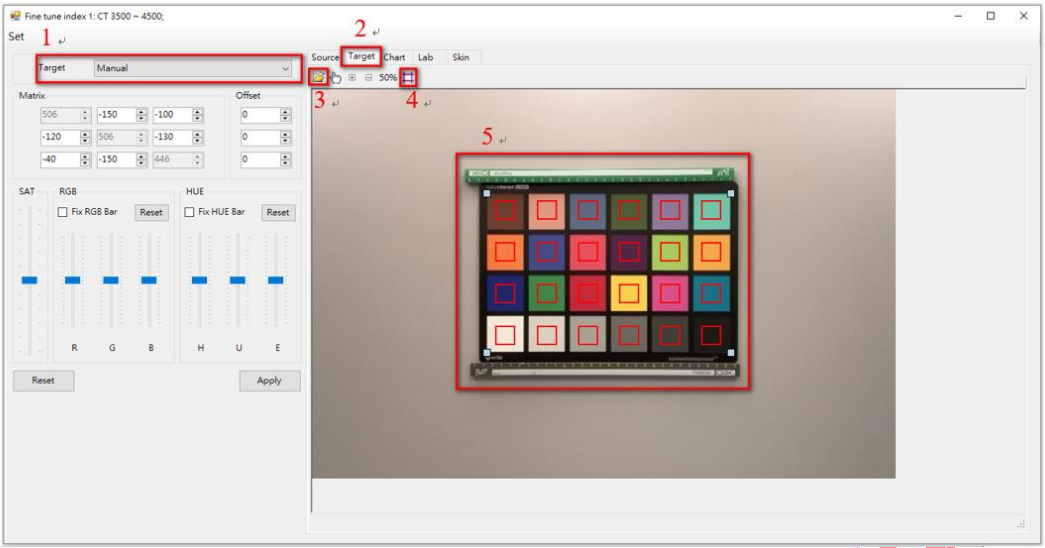


Fig. 5-169

5. Click “optimize” button on “Chart” page to calculate color correction matrix.

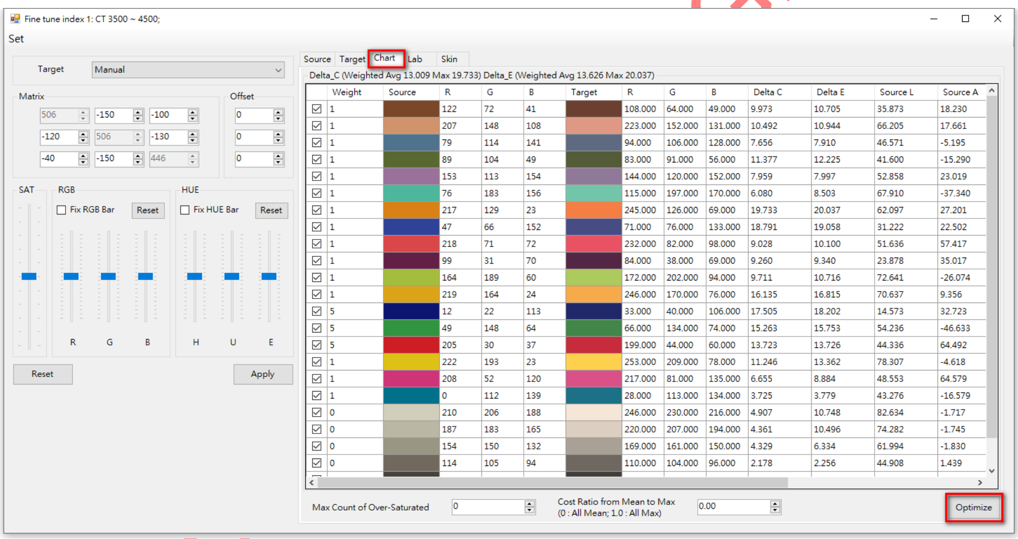


Fig. 5-170

6. Click “Apply” to re-simulation and check simulation result. Analysis for this simulation or fine tune manually if needed.

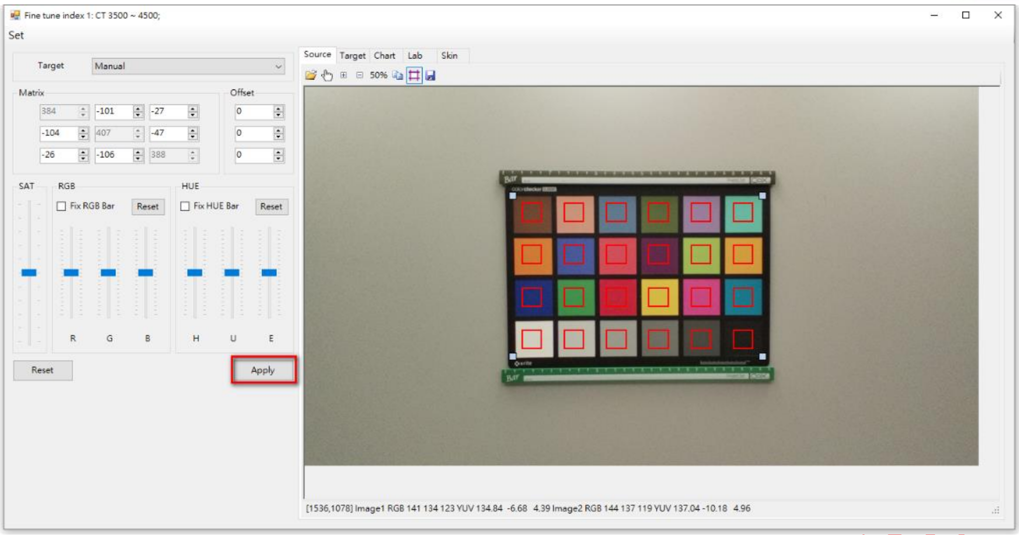


Fig. 5-171

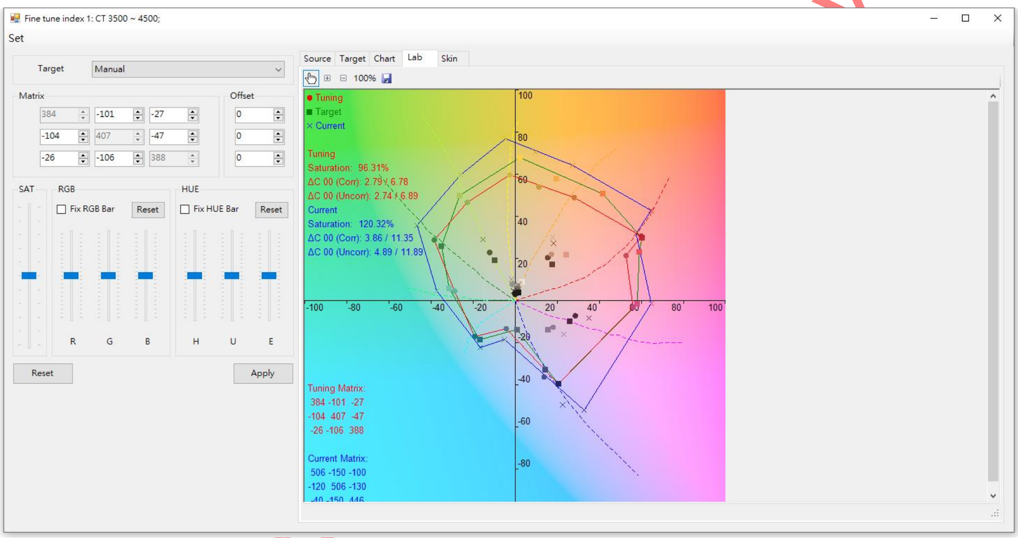


Fig. 5-172

7. Click “Set”, the parameters will be updated to CCM main page.

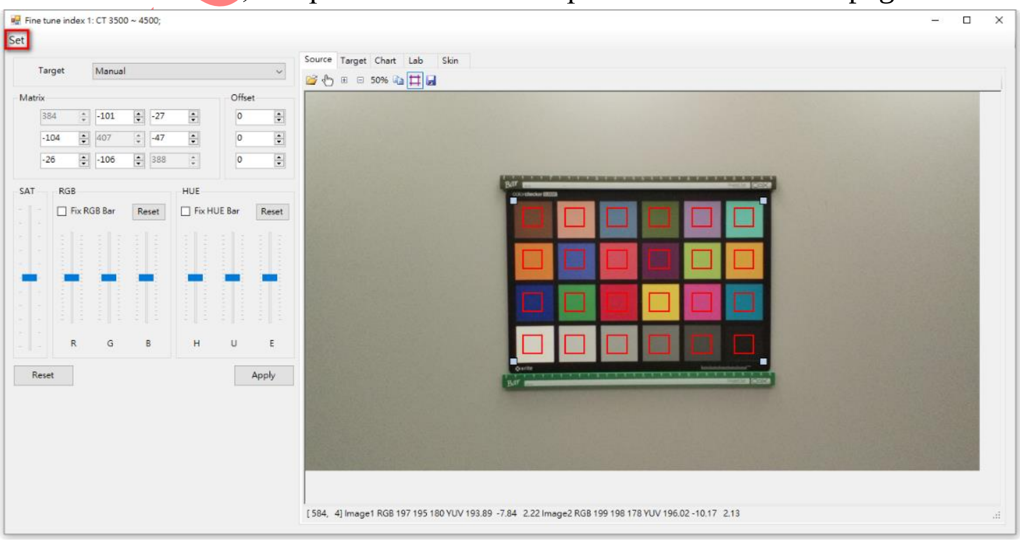


Fig. 5-173

For the tuning of the three parameters: “Clip level”, “Protect range” and “CCM decimal”, please refer to the article “[Improvement for color tint (face case)]”.

5.13.2. BCCM

The target of blended CCM is prevent the false color be enhanced when raising the colorfulness at CCM module, and reduce CCM colorfulness more when the color closer the neutral color.

This function is an extension of CCM for reducing false color. By interpolating CCM coefficient in different chroma region, we can limit color noise be not enhanced.

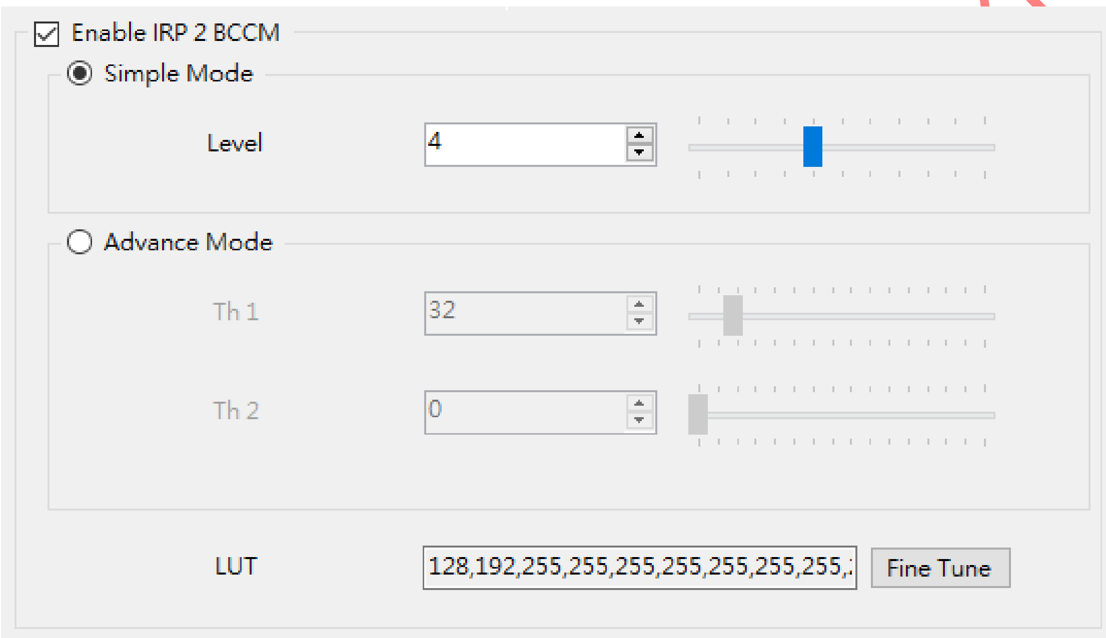


Fig. 5-174

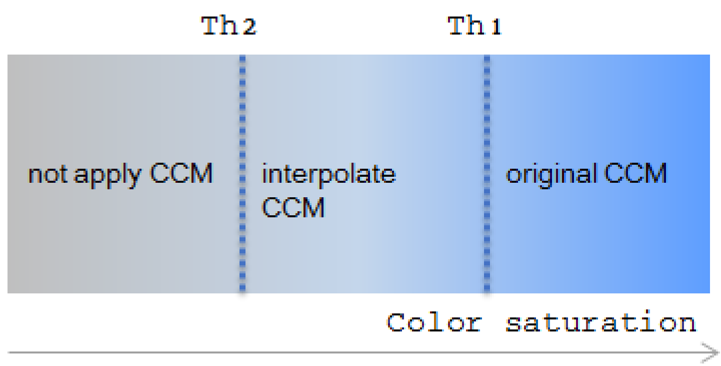


Fig. 5-175 Th 1&2 definition

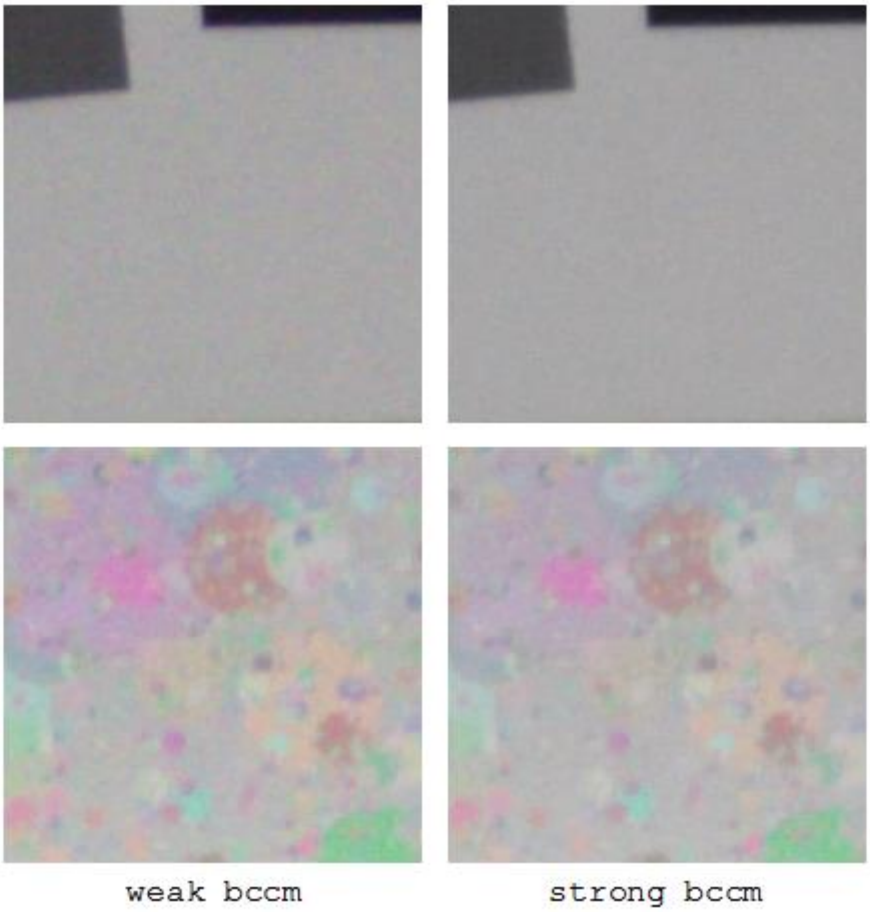


Fig. 5-176 BCCM example

Although BCCM limit color in noise region but also effect color texture.

5.13.3. Gamma

The human eyes perceive light in a different way than the cameras. The Gamma function provides a nonlinear mapping to fit the human eyes.
(Note that there is only one set of Gamma throughout different gain triggered parameters)

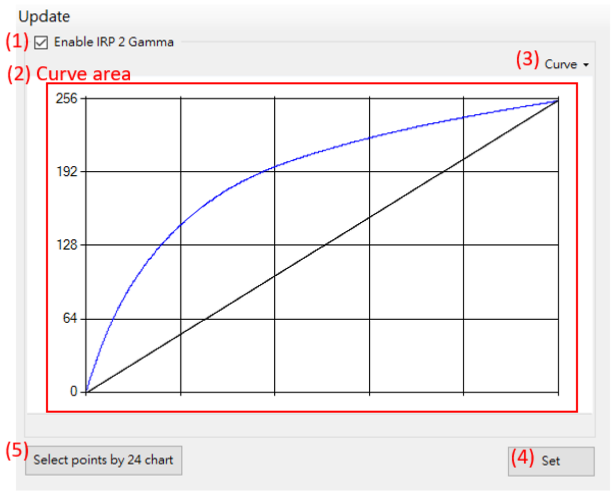


Fig. 5-177

- **Enable/Disable Gamma**

  Disable Gamma will get a linear gamma curve

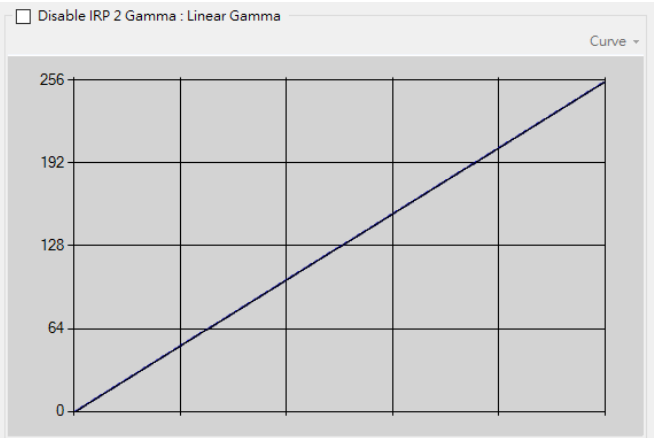


Fig. 5-178

- **Curve area:** Allows user to add control point on the curve and generate smooth non-linear curve. Left click by mouse to add point, and press the "Del" by keyboard to delete the point. When a point is selected, the points show green color, the users can drag around or use the keyboard (up, down, left, right) to generate new curve. It is recommended to use tool default curve.
- **Curve function**

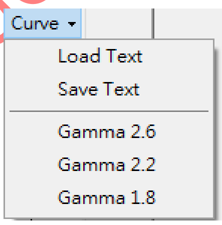


Fig. 5-179

Save text: Save the current curve into a text file.

Load text: Load a text file curve. The user can save a text and see the format before load a text.

Gamma 2.6/2.2/1.8: Default gamma curve for reference

- **Set:** Apply gamma to simulation result
- **Select points by 24 color chart**

  The user can create a gamma curve by a target 24 color chart image.

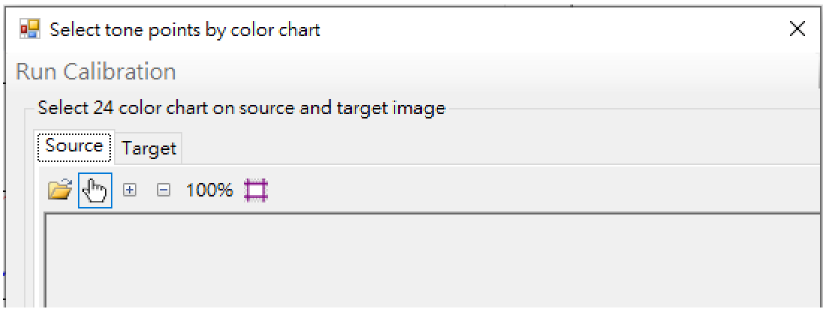
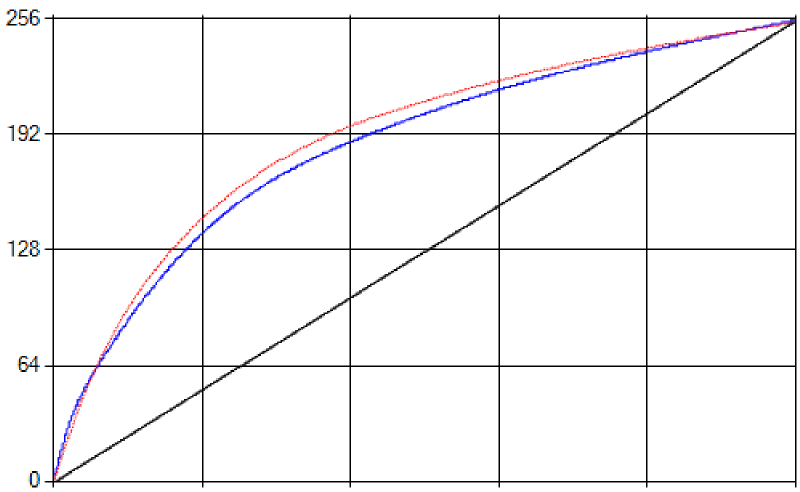


Fig. 5-180

Follow steps as below,

i. Load a raw image for source
ii. Select 24 patches on source image with this button:
iii. Load a jpeg or bmp image for target
iv. Select 24 patches on target image with this button:
v. Start "Run Calibration"
vi. The new gamma curve will be displayed in the curve area



Blue: new curve, Red: original curve

5.13.4. RGB2YUV

Convert RGB to YUV, currently set BT601 as default setting.

5.13.5. IRP 2 CS

5.13.5.1. Chroma suppression

The chroma suppression enforce the false color close neutral to become more close neutral color actually in CbCr domain. At LUT mode, the color distance apart

from the neutral be suppressed could be tuned by a threshold, and the suppress strength could be tuned by a LUT. Besides, if Y is smaller than a pre-defined threshold, it will do nothing at chroma suppression.
At Linear mode, the Cb/Cr values would be suppressed with linear equation by the different cutoff threshold, slope and offset setting.

【LUT mode】

- Decrease saturation by LUT
  - □ (CbCr < Th && Y > Luminance Th) → mapping CbCr by LUT
  - □ In dark area, CbCr is small and easily to be suppressed. If only want to reduce brightness area, you can set the Luminance Th.

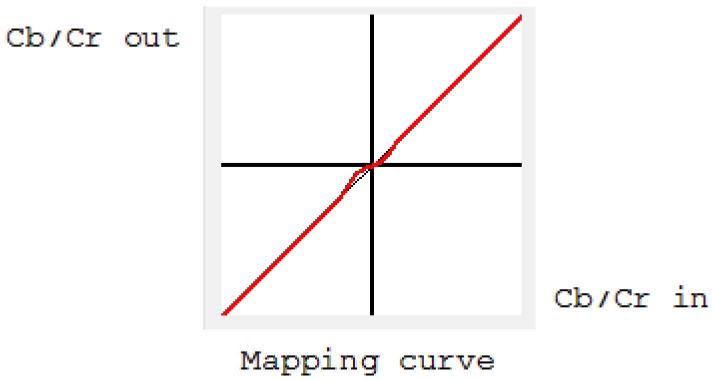
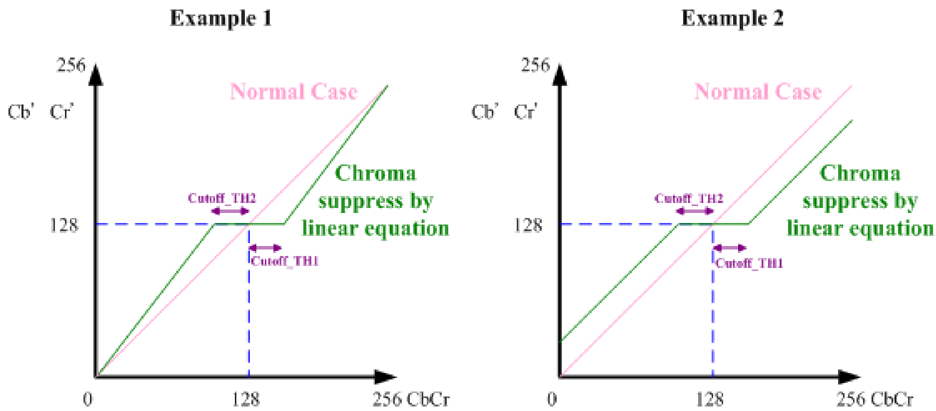


Fig. 5-181 Chroma Suppress LUT mode

【Linear equation mode】

- Mapping CbCr value by linear equation
- Like LUT mode, linear equation mode also could be represented to a transfer function. However, we suggest use LUT mode first, because it is more accurate for controlling.



slop = (1024 * Cutoff_TH)/(128 + Cutoff_TH) slop = 0

Fig. 5-182 Chroma Suppress linear equation mode

5.13.5.2. Cb Cr 444 Blur

CbCr 444 Blur reduces false color by applying a 5 x 5 mask on Cb and Cr channels.

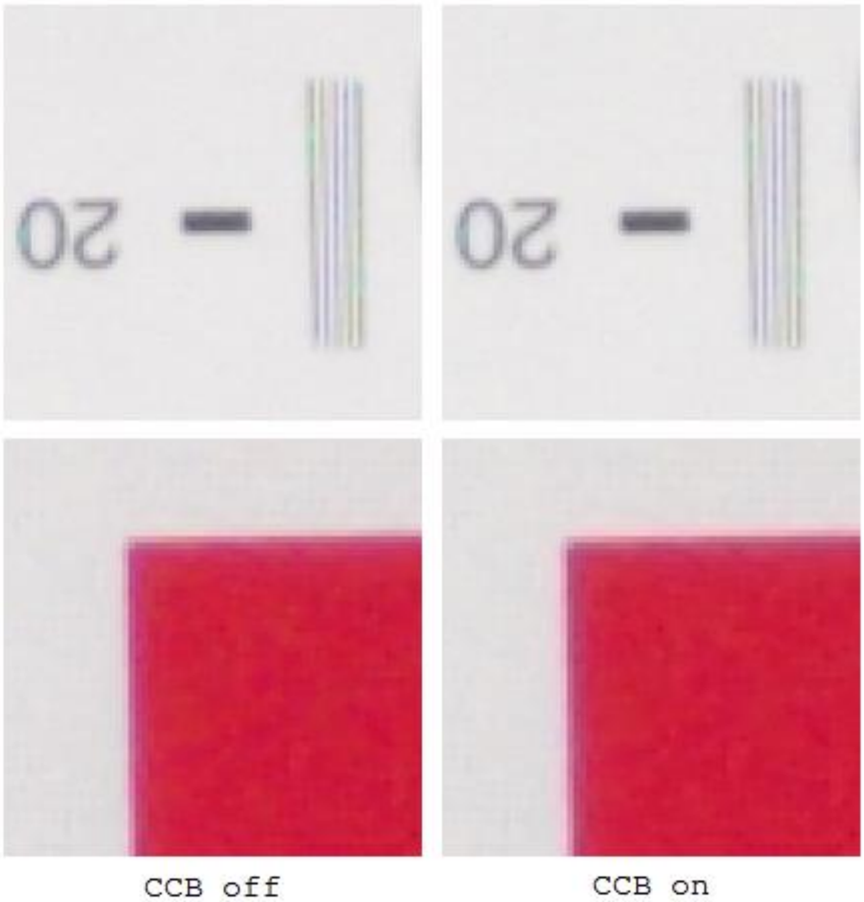


Fig. 5-183 Chroma Suppress CCB example

5.13.5.3. Y Guided Chroma Suppression

Y guided chroma suppression enforce the false color close neutral in low or high luminance area to become more close neutral color actually in CbCr domain.

YCS is an advance version of CS. It reference Y intensity for guiding suppressed level. There are 2 weighting curve of this function, one is defined by Y intensity, the other is by chroma difference. Combine these 2 weightings to decide final suppress level.

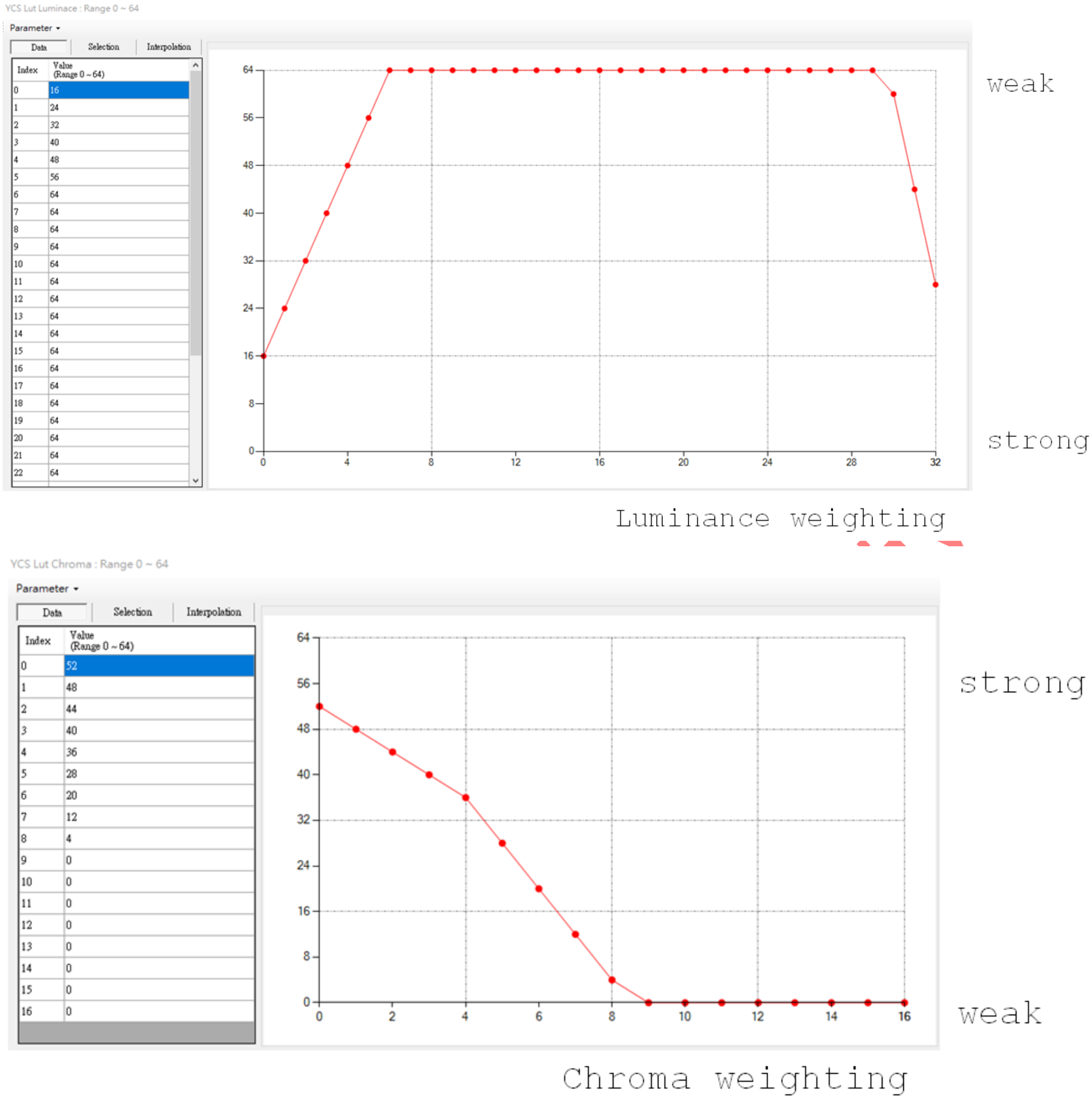


Fig. 5-184 Chroma Suppress YCS

Suppress color not refer to Y

Suppress more color on dark and bright region

Fig. 5-185 Chroma Suppress YCS example

5.14. Post Processing

Post processing engine combines one operations: Adjust Cb Cr by 2DLUT method. 2D LUT is a kind of color transformation process, this algorithm uses Cb/Cr as input and combine with Y channel for reference. User can define 32 x 32 Cb/Cr LUT to find desired remapping color. At last, an input Cb/Cr can map to a new desired output Cb/Cr result.

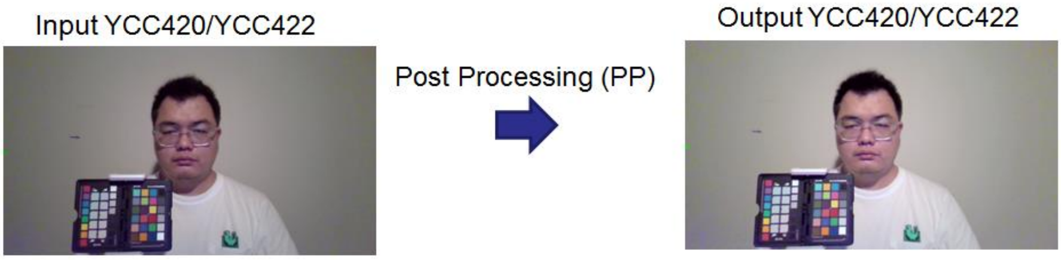


Fig. 5-186 Post Processing result

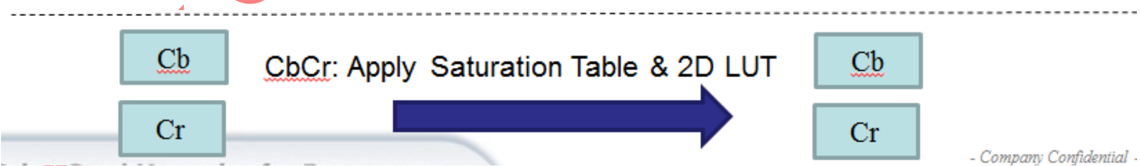


Fig. 5-187 Post Processing flow

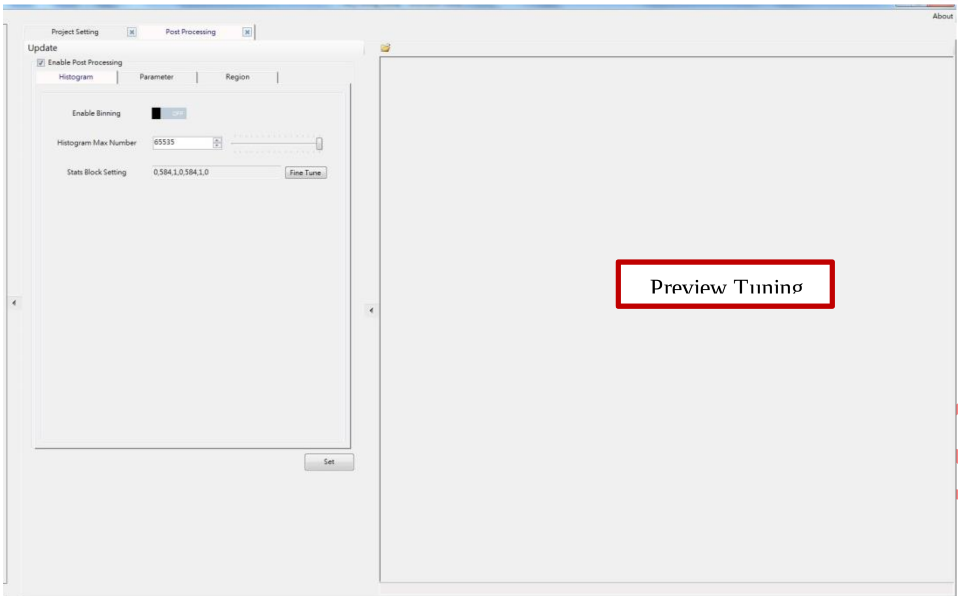


Fig. 5-188 Basic GUI of Post Processing

5.14.1. Tuning Process:

- Set trigger point of Color Temperature (CT)
- Select candidate region to tune color transformation

5.14.2. Basic flow control parameter

Please refer to fig. 5.154, basic flow control flow page

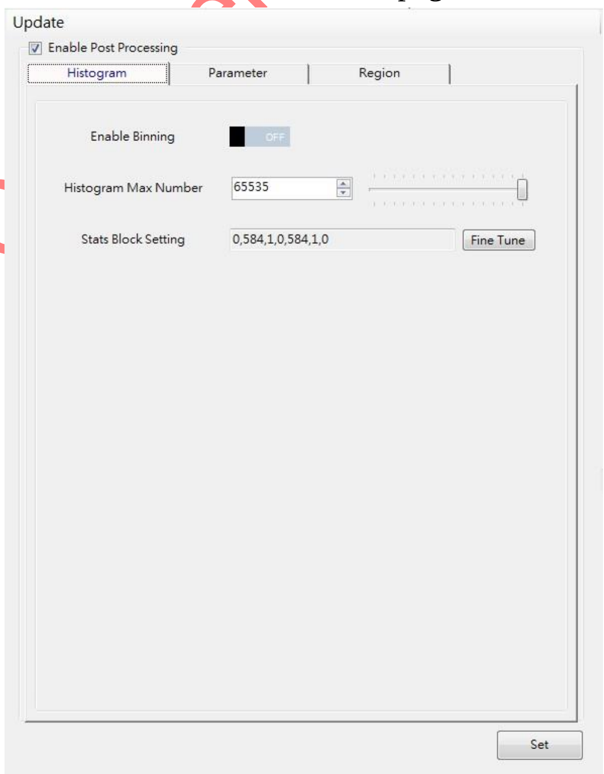


Fig. 5-189 Basic control parameter (Histogram)

- Enable Binning
  - Calculate binning histogram. For large image, the histogram statistic will overflow, so the image must scale down through the binning method.
- Histogram Max Binning
  - Max number of histogram's counts. Range from [0~65535]
- Stats Block setting
  - Set histogram statistic region.

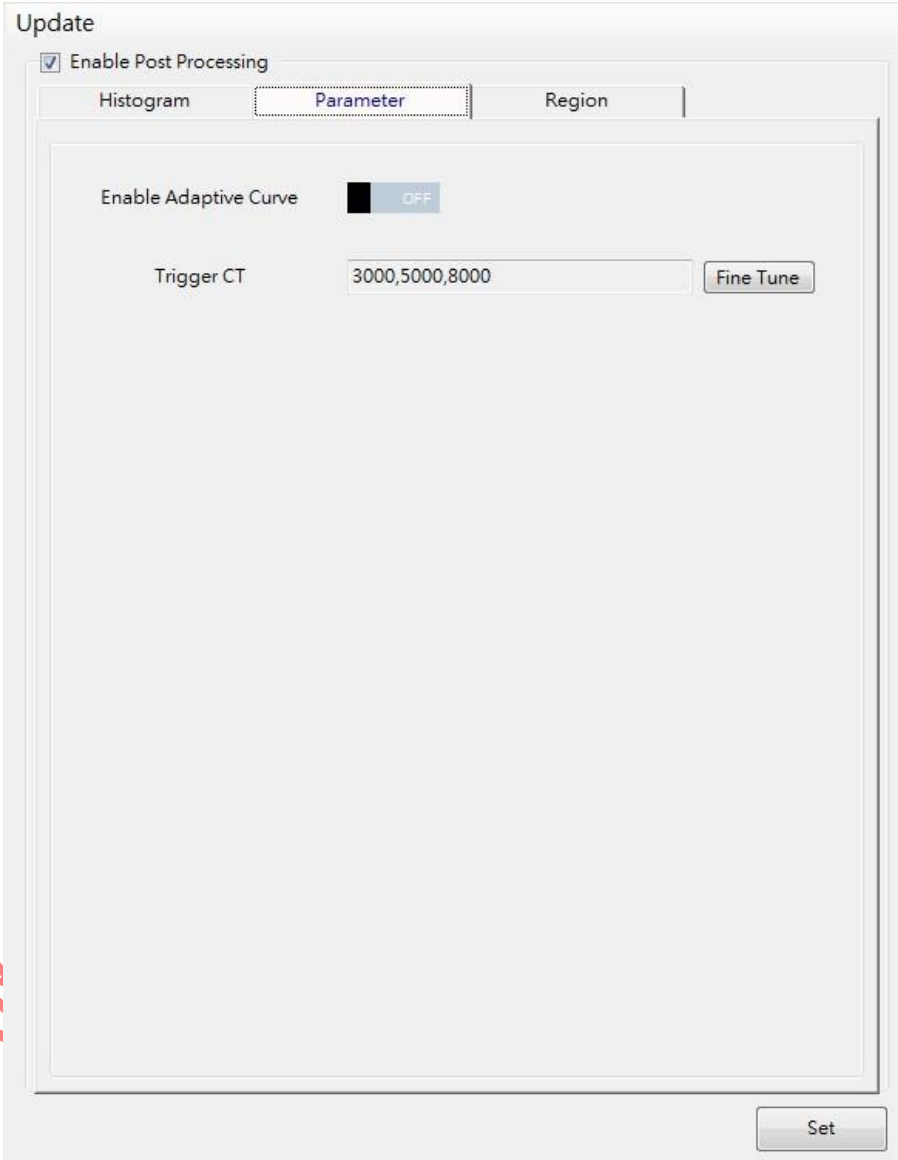


Fig. 5-190 Basic control parameter

- Enable Adaptive Curve
  - Control shading weight's influence on 2D LUT.
- Trigger CT
  - Different color temperature's trigger point.
  - CT Low/ CT Mid/ CT High

5.14.3. Select Region and Tune color

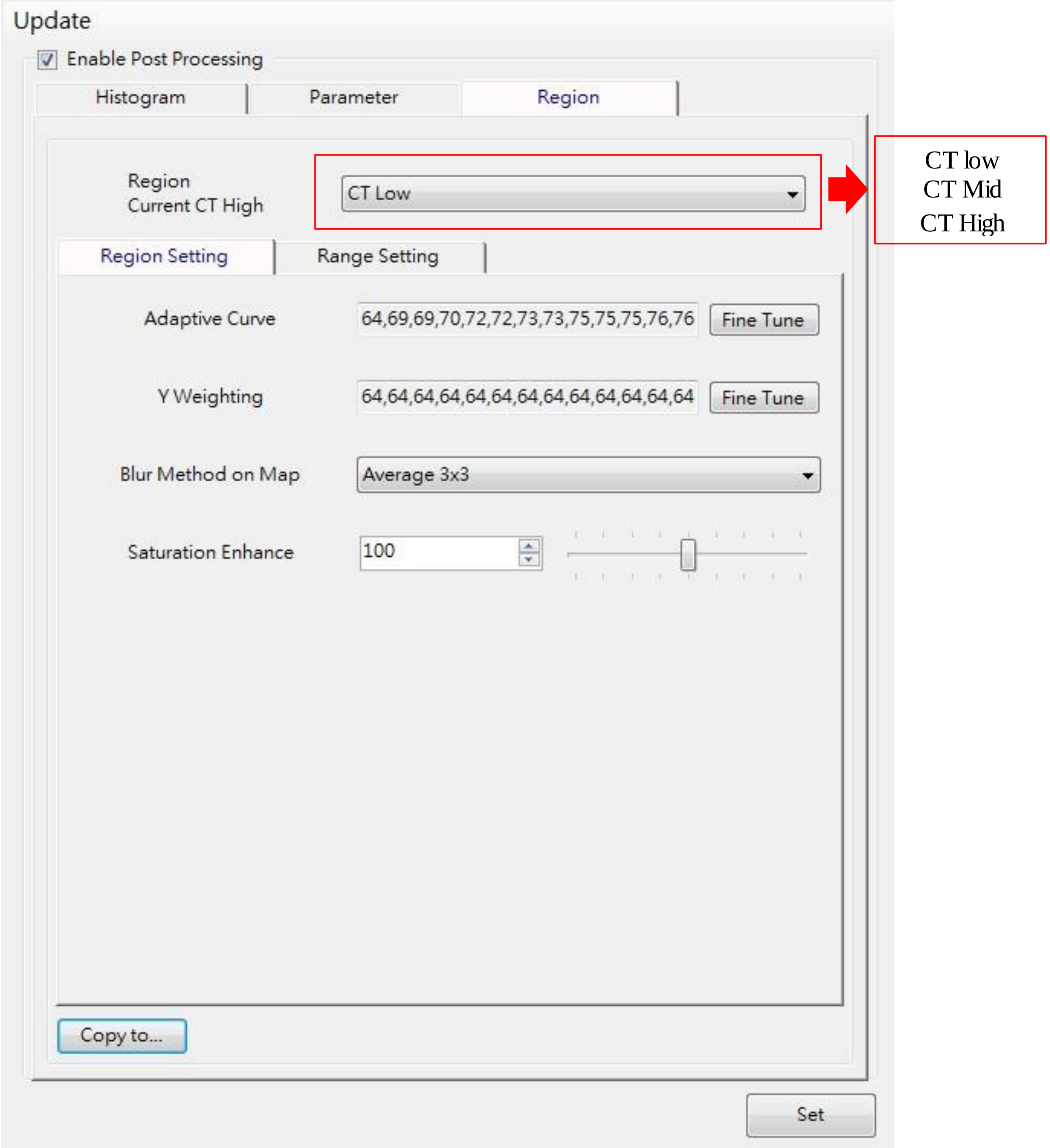


Fig. 5-191 Region tuning parameter

- Adaptive Curve
  - Apply different weighting on center corner region
  - Weight < 64 => Reduce 2D LUT effect.
  - Weight > 64 => Enhance 2D LUT effect.

It separate 33 nodes for user to tune different weighting on center/corner

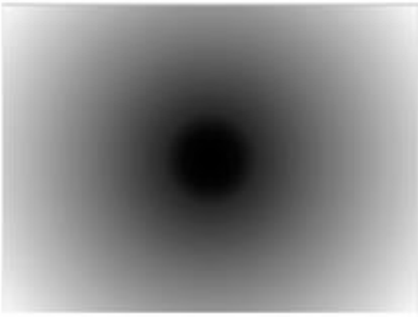


Fig. 5-192 Shading(Adaptive curve)

- Y Weighting
  - Base on Y(Luminance) intensity to reduce/enhance 2D LUT effect.
  - Node : 0, 16, 32, 48, 64, 80, 96, 112, 128, 144, 160, 176, 192, 208, 224, 240, 256
  - Weight < 64 => Reduce 2D LUT effect.
  - Weight > 64 => Enhance 2D LUT effect.

- Blur Method on Map
  - Apply on 2D LUT to smooth every tuning color range (Range 0~3).
  - Average 3x3
  - Gaussian 3x3
  - Gaussian 5x5

- Saturation Enhance
  - Globally enhance saturation
  - Range: [0 ~ 200]. Base is 100.

5.14.4. Color range settings

Tuning tool converts original hardware Y tone table and 32x32 Cb/Cr LUT into HSV domain for intuitive tuning.

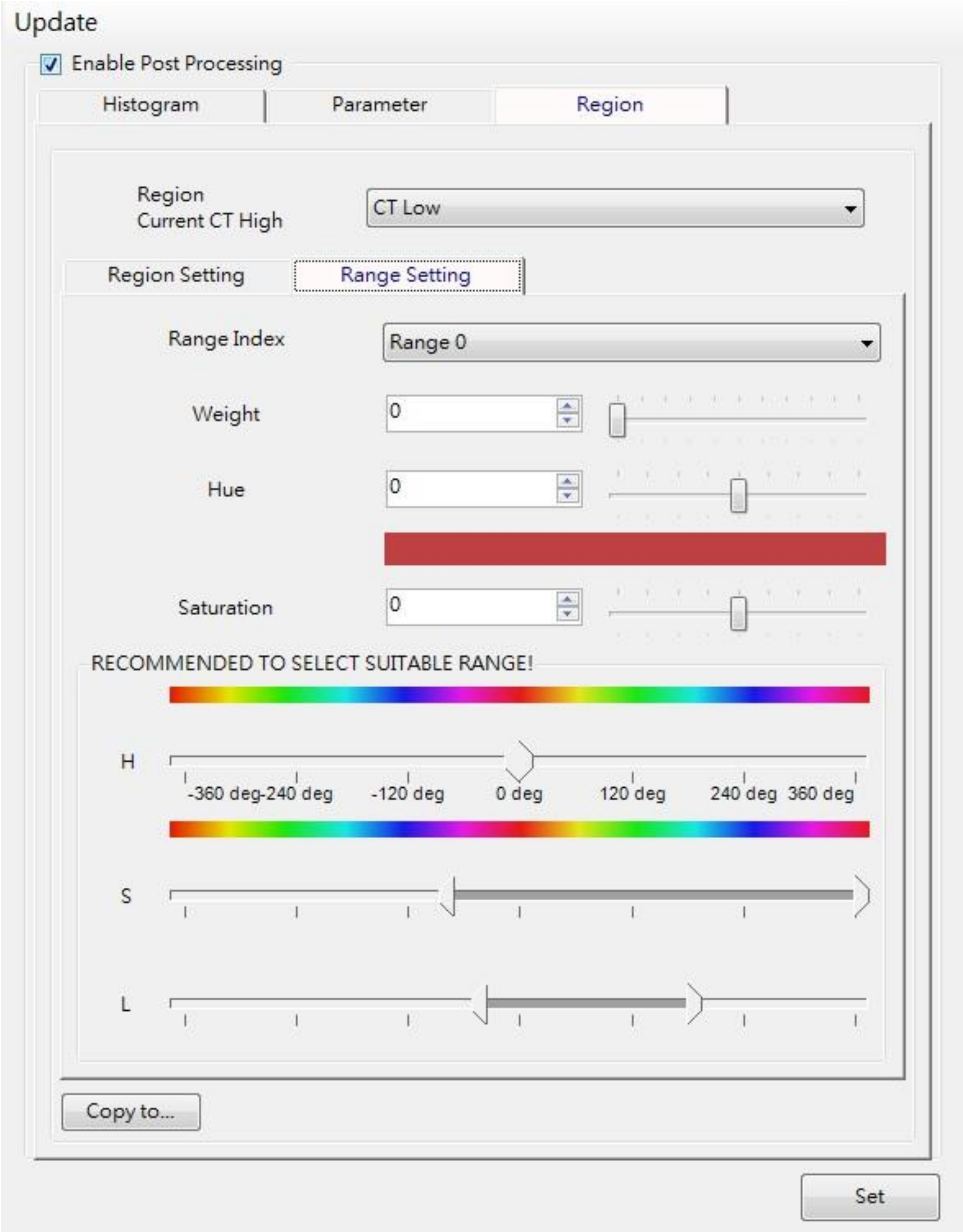


Fig. 5-193 Color Range Setting

- ■ Range Index
  - □ Support 4 range tuning combination
- ■ Weight
  - □ Each range(Range 0~ 4) map's weight
  - □ Range : [0~100]
- ■ Hue
  - □ 0 : Red
  - □ 120 : Green

- ☐ 240 : Blue
- ☐ Limitation : +/- 10 degree
- ☐ Range: [-5000~5000]. Base is 100

■ Saturation

- ☐ Range:[-5000~5000]. Base is 100
- ☐ Limitation : +/- 10%

5.14.5.Helper UI

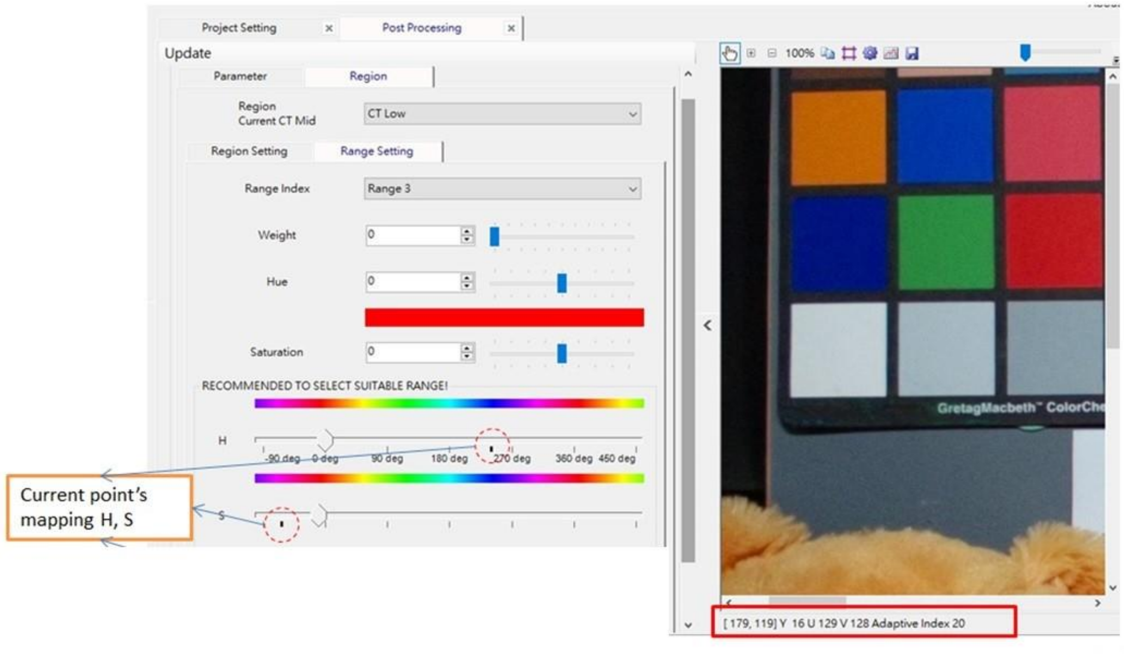


Fig. 5-194 Helper UI

5.14.6. Tuning Step (UI Explanation)

1. Tuning one range (ex: Range1)
2. Range's weight (ex: apply 60% Range1's map)
3. Mouse move to red rectangle region, it will show YUV information and its coordinates.
4. Stretch bar in mapping H/S (Must contain current H/S).
5. Tuning Hue/ Saturation depend on user's preference.

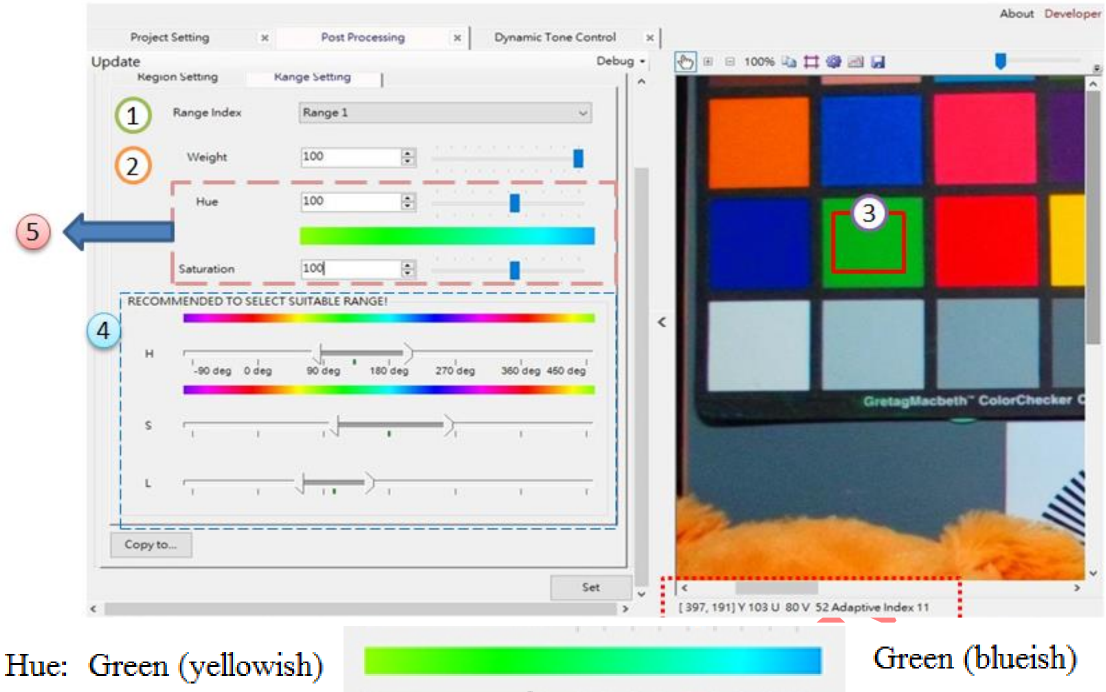


Fig. 5-195 Post processing tuning step UI explanation

5.15. Sharpness

Sharpness aims to enhance edge contrast of input image, it doesn't really add resolution._Sharpness only works on Y channel. If user prefers high edge contrast, it can be tuned according to preference, example is shown below:

Fig. 5-196 Sharpness overall goal

5.15.1. Tuning Process

- Tuning order:

  Filter→Intensity→Feature→Laplacian→Luminance→Map

It is suggested to tune by sub-page order.

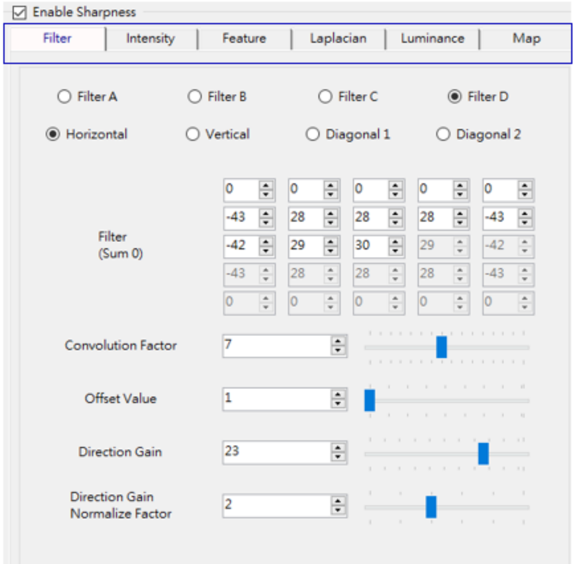


Fig. 5-197 Sharpness overall tuning sub-pages

5.15.2. Tunings for "Filter" sub-page

- 5x5 filter is used to get filter response
  - ☐ There are four filter groups: FilterA, FilterB, FilterC, FilterD
  - ☐ For each group, four directional masks are used: Horizontal, Vertical, Diagonal1, Diagonal2 (+-45 degree)
  - ☐ User can set mask coefficients for Horizontal & Diagonal1; HW will get Vertical & Diagonal2 mask coefficients automatically, the configurable coefficients are a0~a12 & b0~b12, tuning tool can let user set desired values, example is shown below:

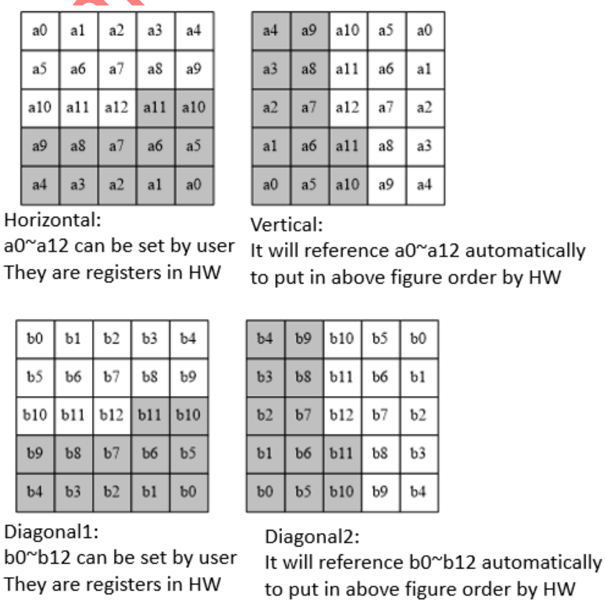


Fig. 5-198 Sharpness: Set mask coefficients

  - ☐ Filter coefficients setting rule:
    1. Let all mask coefficients summation value for a 5x5 filter be zero

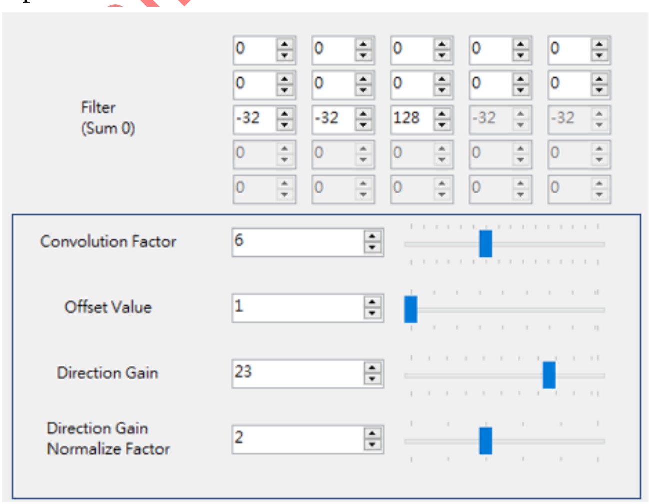
EX:

Fig. 5-199 Observe mask coefficients

2. Data range limitation:
   - a12 (range: -255~+255 ; 9bit)
   - b12 (range: -255~+255 ; 9bit)
   - a6, a7, a8, a11 (range: -127~+127 ; 8bit)
   - b6, b7, b8, b11 (range: -127~+127 ; 8bit)
   - a0, a1, a2, a3, a4, a5, a9, a10:(range: -63~+63: 7 bit)
   - b0, b1, b2, b3, b4, b5, b9, b10:(range: -63~+63: 7 bit)

3. Tuning suggestion:
   - High pass filter coefficients need to be designed carefully, not suitable for random key in numbers. If user doesn't have specific preference, it is suggested to use tool's default coefficients.

- Other filter control values:
  - ☐ Convolution Factor: (Data range: 0~15)
    - ☐ after 5x5 convolution, how many bits for shifting to get response; for example:



Filter control settings

Fig. 5-200 Filter control related values

After convolution, needing to do bit shift to limit the data range, convolution factor means the bit shift amount. In often, user can estimate the summation value of positive coefficients, in above example, summation value is 128, convolution factor is 6, it means that convolution result will do bit shift of 6 (equal to divide by 64). This step aims to shrink data range before further signal estimation steps. For suggestion, if positive coefficient summation value is around 64, let convolution factor be 5; if positive coefficient summation value is around 128, let convolution factor be 6; if positive coefficient summation value is around 256, let convolution factor be 7; these settings are often used for general tunings, the signal range will not be enlarged too much or shrunk too much. User can reference this suggestion.

- Offset value: (Data range: 0~ 511)
  - It will do data offset after convolution, when convolution factor is too low, then data range is enlarged after convolution, the offset value needs to set as high value, that’s why this value’s data range is not so limited. In often usage, if user use tool’s default mask coefficient & convolution factor, because that data range is controlled, then offset value is suggested to be tuned in range of 0~3. Higher offset value help remove too small signal after convolution, it can help reduce smooth area noise. Example is shown below:

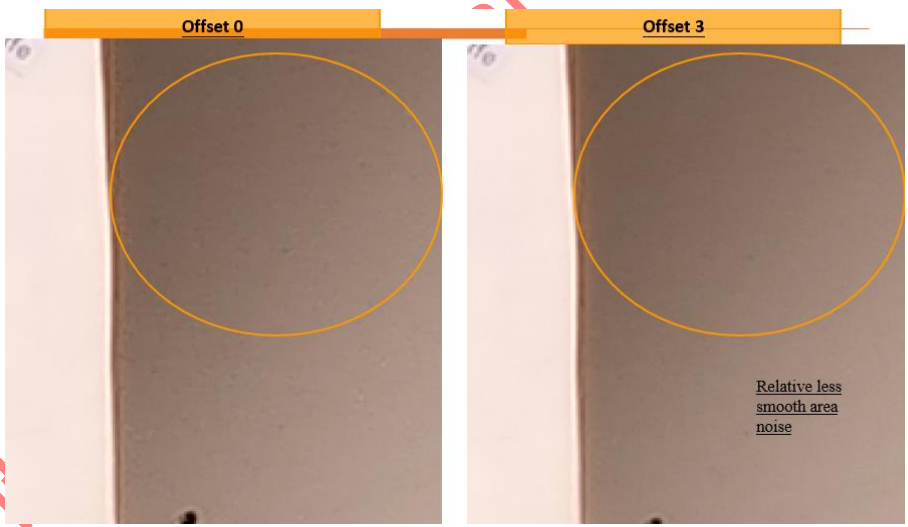


Fig. 5-201 simulation example of different filter offset value

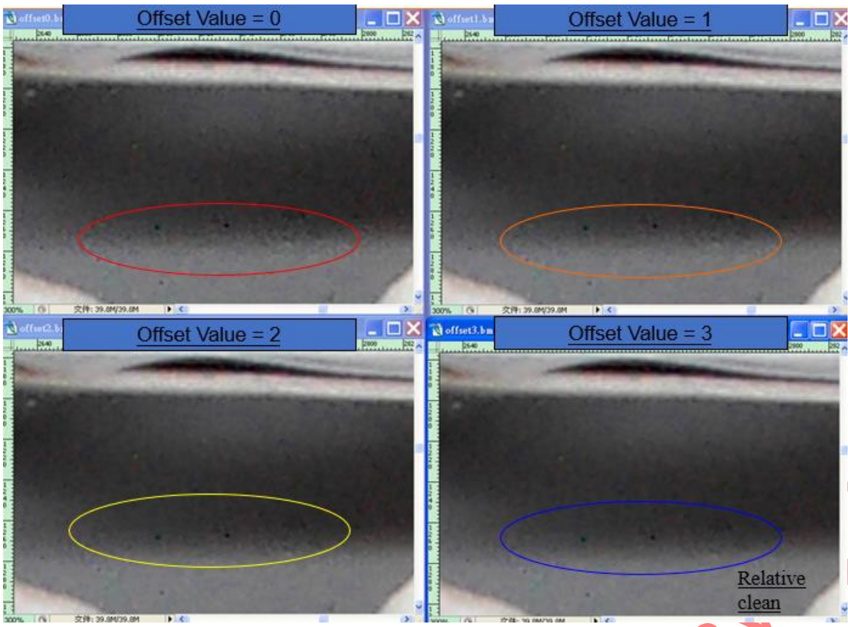


Fig. 5-202 simulation example of different filter offset value

- ☐ Direction gain: (Data range: 0~ 31)
  - ☐ Each direction can set different direction gain. Higher gain value can let response be increased. For suggestion, letting each direction using same gain value will be preferred. If user prefers to enhance specific direction's filter response, then let each direction have obvious different gain value. For example: only let horizontal or vertical direction has gain value, other direction gain value set as zero, the comparison is shown below:

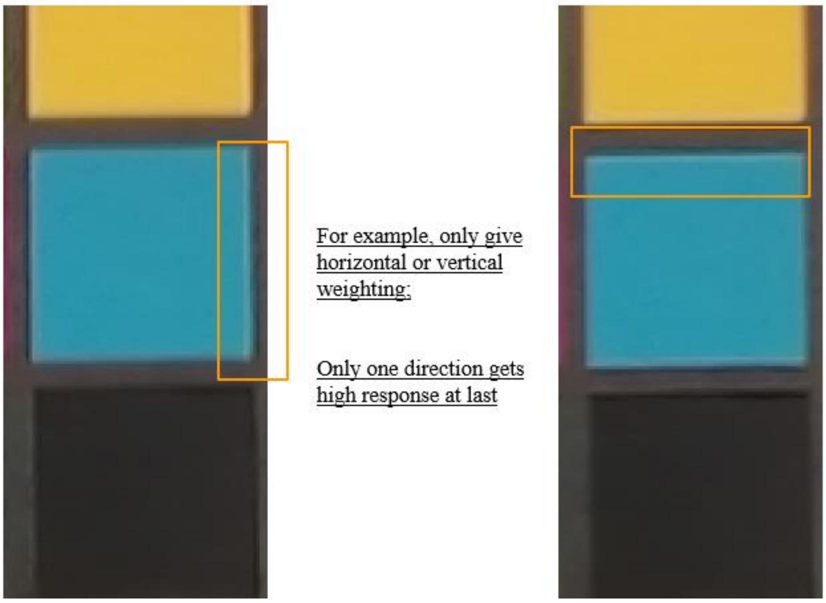


Fig. 5-203 simulation example of different filter directional gain

- ☐ Direction Gain Normalize Factor (Data range: 0~5)
  - ☐ After multiplying with direction gain, signal needs to do bit shift for controlling data range. This value means the bit shift amount. For example, direction gain is 16, however, direction gain normalized factor

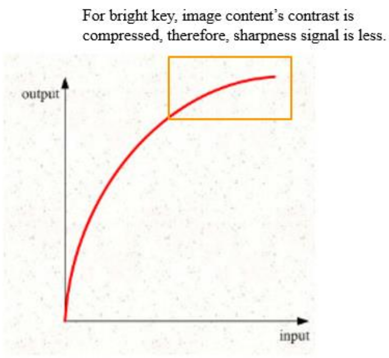
is only set as 3, it means that signal after direction gain is enlarged by 2x, because only do bit shift of 3 (equal to divide by 8).

- Overall suggestion for tuning of this sub-page
  - For this subpage, all settings are rarely tuned, user can just keep default mask coefficient, set all of direction gain as 31 (equal weighting and let it be higher), set offset value as 1, for other items, if no specific preference, can just use tool's default value.

5.15.3. Tunings for "Intensity" sub-page

Because that sharpness's input image often already be processed by specific luminance processing; (for example, high key is already highly compressed by gamma, since input has low contrast in high key, it is hard to get high response for sharpness.) In order to get required sharpness response amount, user can choose preferred LUT content to transform input data before sharpness value estimation. It is noted that input image's intensity is not really changed by this LUT at last, just use the transformed data for sharpness analysis. An example of high key input problem is shown below:

High key has lower contrast because of gamma transform.

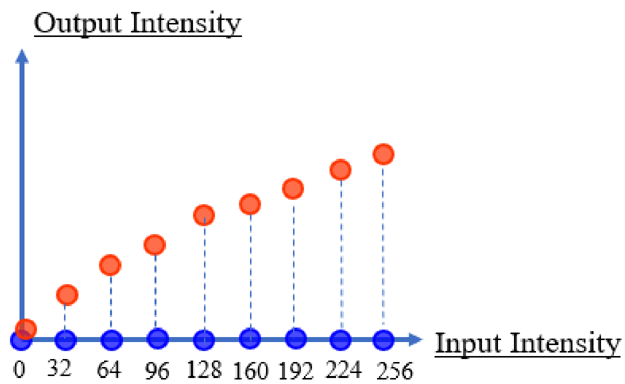


Sharpness input already apply gamma curve

Fig. 5-204 Example of high key already be compressed too much before sharpness

- Goal: Let input intensity transform into output intensity by a LUT before further sharpness estimation; (just for internal analysis usage, it will not change output image's pixel intensity by this LUT)

- Output intensity end point amount: 9
  (The mapping input intensity position is shown in below figure;
  (Linear interpolation will be done to get full mapping relationship)



Input Intensity	Mapping output intensity
0	Element1
32	Element2
64	Element3
96	Element4
128	Element5
160	Element6
192	Element7
224	Element8
256	Element9

Fig. 5-205 Tuning item in LUT of intensity sub-page

Two methods for tuning this LUT:

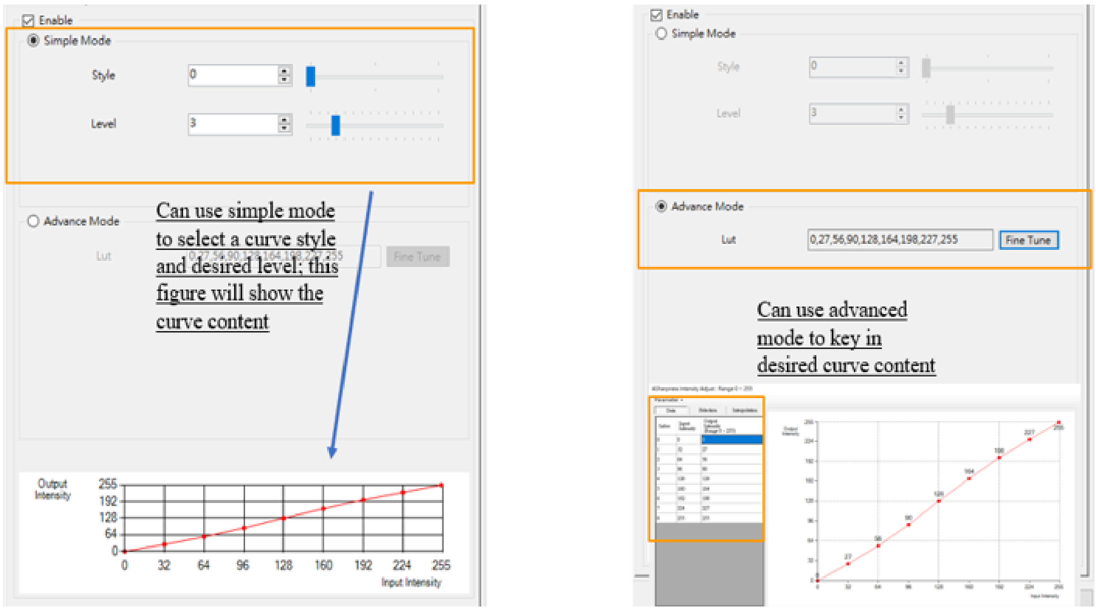
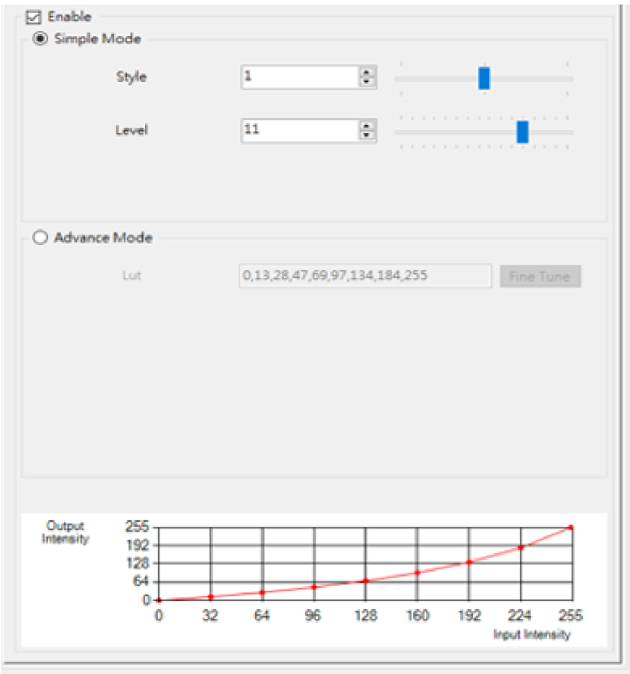


Fig. 5-206 Tuning intensity LUT by simple mode and advanced mode

An example of enlarging contrast for high key is shown below:



Input Intensity	Mapping output intensity
0	0
32	13
64	28
96	47
128	69
160	97
192	134
224	184
256	255

Enhance contrast in bright key

Fig. 5-207 Example of high key boosting by LUT

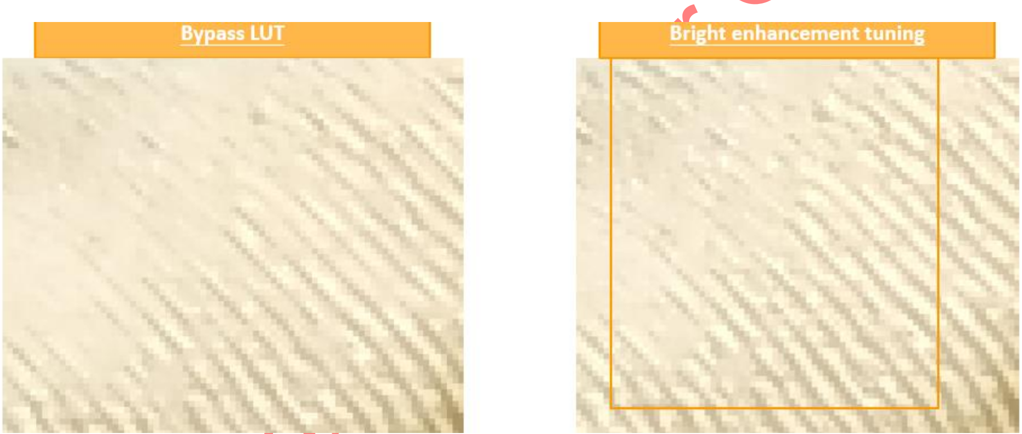


Fig. 5-208 Example of high key boosting by LUT

Suggestion for tuning:

→If input image is high compressed for specific luminance region, user can compensate its impact by tune corresponding intensity LUT. In general, the intensity LUT is suggested to be "bypass".

5.15.4. Tunings for "Feature" sub-page

For descriptions and given tuning examples, it is supposed that user just using tool's default settings in "Filter" sub-page.

There are three main jobs for this sub-page:

1. Determines sharpness style. (thin to thick sharpness)
2. Determines sharpness feature gain for smooth area to hard edge
3. To avoid single outlier pixel over-enhancement or not

Avoiding too much sharpness enhancement for outlier pixel can be done by "Enable outlier removal". Tuning method and example are shown below:

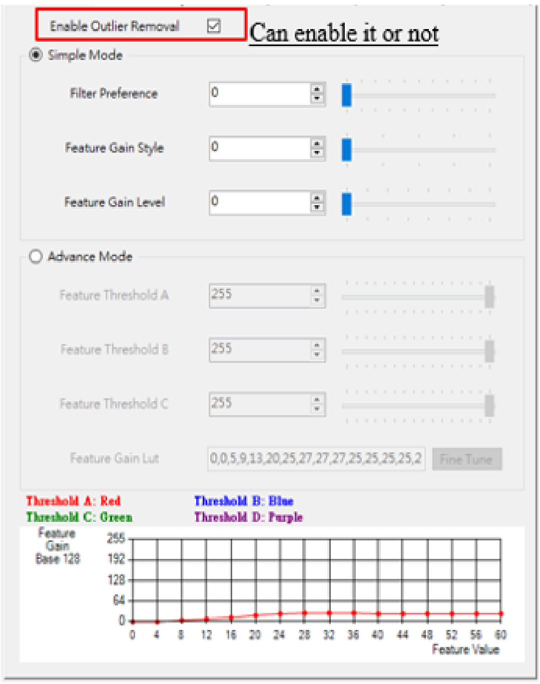


Fig. 5-209 Tune outlier removal by check box

- Enable → Avoid over-enhancement for single outlier noisy pixel
- Suggestion for tuning: let it be "Enable"

Avoid single outlier noisy pixel too much sharpness enhancement

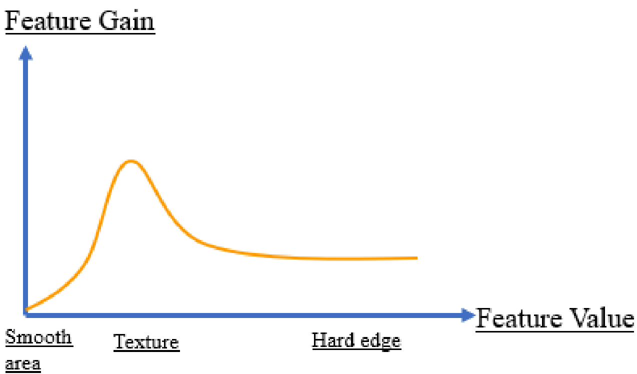
Fig. 5-210 Example of outlier removal enable

Next step is tuning feature gain curve. In this curve, X-Axis means "Feature Value", its end point positions are fixed, user can't tune for end point position. User needs to tune the Y-Axis content, it means "Feature Gain" value. In other words, user needs to tune each fixed feature value's corresponding feature gain value. For different input feature value (from low feature value to high feature value, it means smooth area to hard edge), user can control desired feature gain strength. Feature gain meaning is shown below:

- ☐ Feature gain data range: 0~255; it is 128 based
- ☐ Feature gain < 128 → Decrease sharpness response
- ☐ Feature gain = 128 → Keep original sharpness response
- ☐ Feature Gain > 128 → Enhance more sharpness response

As below Figure8.23-10, the X-Axis feature value content is fixed, there are sixteen end points from 0, 4, 8, 12….60, therefore, user needs to tune 16 end points for these feature values' corresponding feature gain content. If input pixel locates on smooth area, in often, its feature value will be low. If input pixel is located around hard edge, in often, its feature value will be high. Feature value is estimated by HW, user just assigns their mapping feature gain value. When getting an input pixel's feature value by HW, referencing this curve, then getting this input pixel's feature gain value. User needs to assign each feature value's corresponding "Feature Gain" content, therefore, total needing to tune 16 "Feature Gain" contents.

- ■ Feature gain content: 16 end points
  (As below figure "Feature Value" is fixed, only can tune "Feature Gain")



16 end points mapping method

Index	Feature Value	Feature Gain [illegible] (Range 0 ~ 255)
0	0	0
1	4	16
2	8	32
3	12	40
4	16	50
5	20	64
6	24	64
7	28	64
8	32	64
9	36	64
10	40	64
11	44	64
12	48	64
13	52	64
14	56	64
15	60	64

Fig. 5-211 For different feature value, assign corresponding feature gain

Suggested style for tuning feature gain curve:

- ■ For low feature value end points' mapping feature gain end points, assign low feature gain value
  → Prevent from smooth area noise too obvious

- For middle feature value end points’ mapping feature gain end points, assign high feature gain value
  → Let texture be sharp enough

- For high feature value end points’ mapping feature gain end points, assign middle feature gain value
  → Prevent from too obvious halo at hard edge; need to enhance but not too much

Two tuning methods:

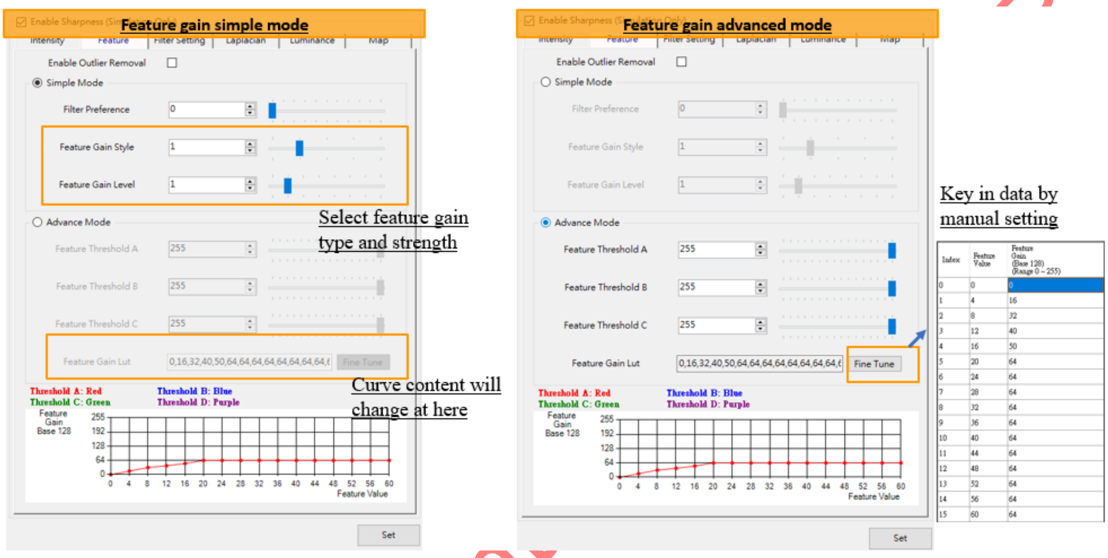


Fig. 5-212 Two kinds of feature gain tuning method

Suggested feature gain tuning method:

- To control smooth area strength → often tuned by this LUT’s element 1, 2
- To control texture area strength → often tuned by this LUT’s element 3, 4, 5
- To control hard edge area strength → often tuned by this LUT’s element 6~ end
- Suggested to let first node be zero.

Tuning examples are shown below:

Example: avoid too much noise enhancement in smooth area:

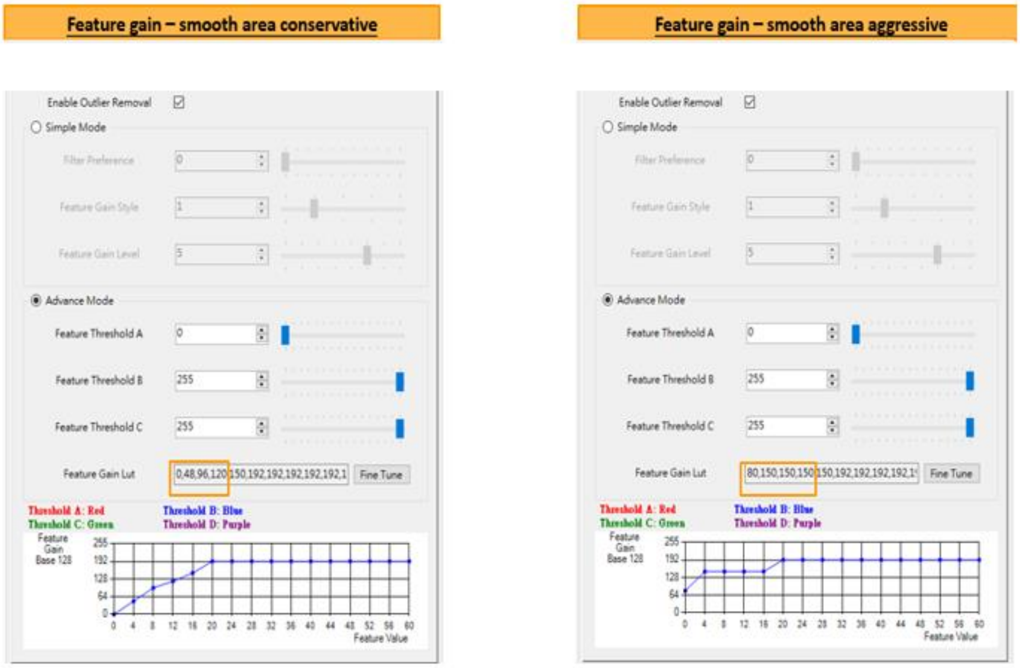


Fig. 5-213 Example of feature gain tuning

If it happens and look too noisy, try to tune lower values for feature gain end point 1~3.

Fig. 5-214 Example of feature gain tuning

Example:

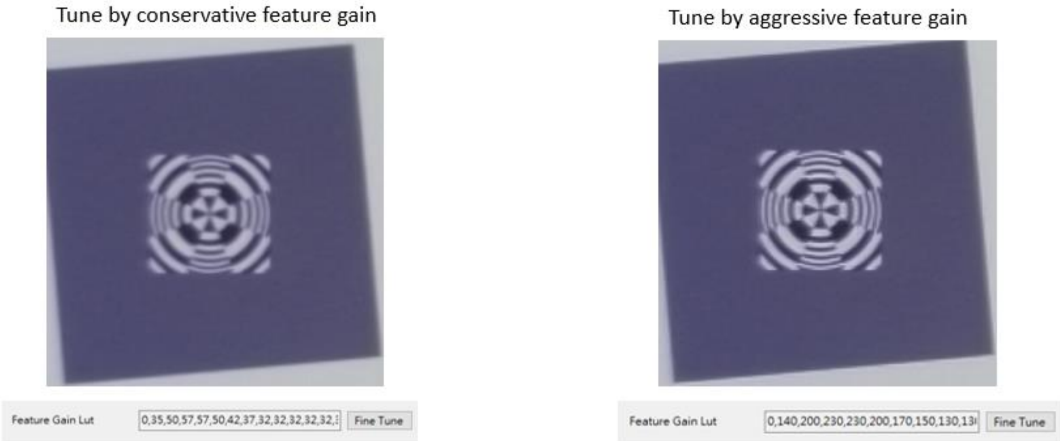


Fig. 5-215 Comparison of different feature gain setting

Suggestion for tuning:

→low iso cases: "Filter Preference" is set as level 6~7,

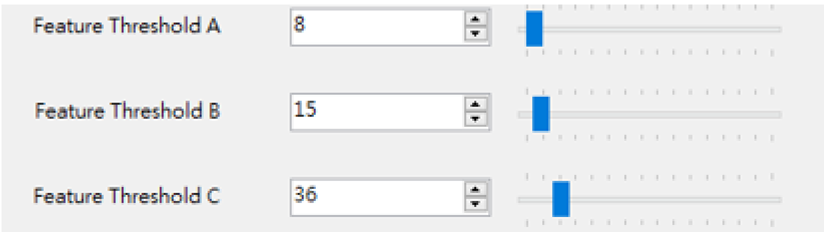
→high iso cases: "Filter Preference" is set as level 9~10.

→"Filter Gain Style" is often set as: 2.

→"Feature Gain Level" is 2~3 for noisy case; 4~5 for clean image case.

■ Feature threshold tuning:

Depend on input pixel's feature value, determining the selected filter group (there are four filter groups, therefore, needing three threshold values to divide them; in here, using tool's default mask setting results for example)



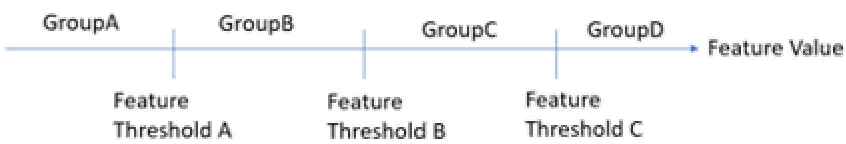
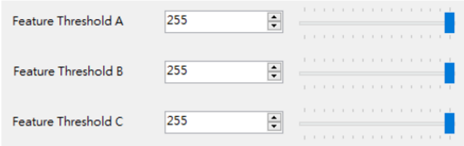


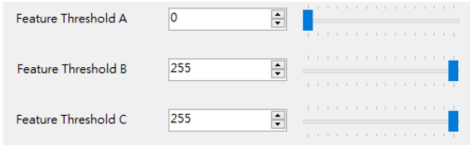
Fig. 5-216 Concept of feature threshold

- ☐ GroupA: choosing thin sharpness style
- ☐ GroupB, Group C: suitable for texture area
- ☐ GroupD: choosing thick & uniform sharpness style to prevent from ugly & non-smooth hard edge

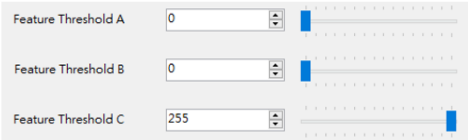
Examples of tuning results are shown below:



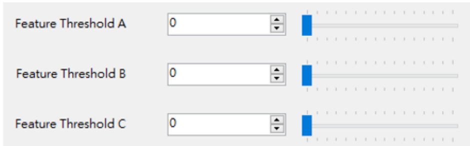
(mainly using GroupA)



(mainly using GroupB)



(mainly using GroupC)



(mainly using GroupD)

Fig. 5-217 Feature threshold setting example

For hard edge, smooth and uniform response is better, therefore, rgoupC, group D are preferred.

Thick and uniform

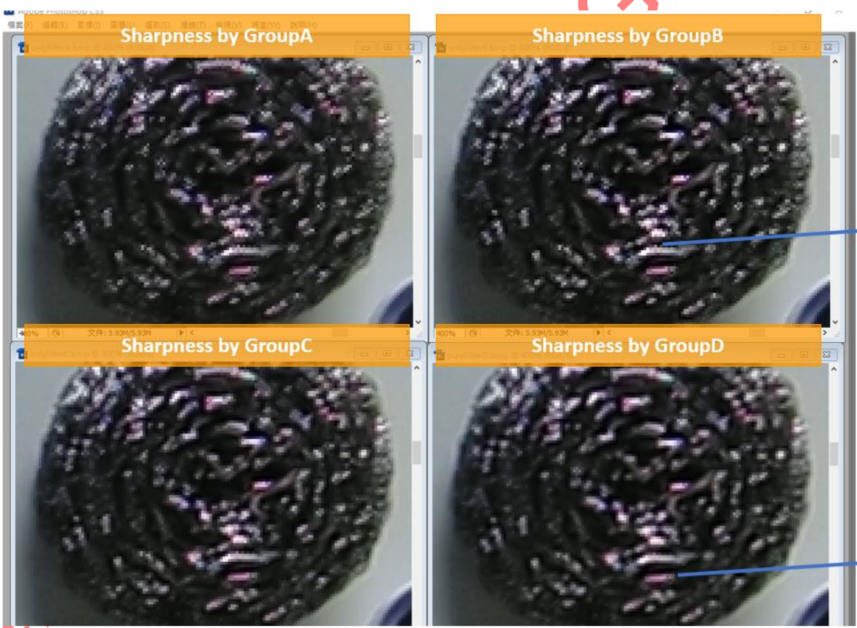
Fig. 5-218 Corresponding result by example setting

Hard edge area behavior

– GroupC~D is better

Fig. 5-219 Corresponding result by example setting

For texture, somewhat higher variance sharpness help let texture look natural, therefore, groupB is better than group D.



Higher variance

Thick and uniform

Fig. 5-220 Corresponding result by example setting

Smooth area behavior – GroupA~B is better

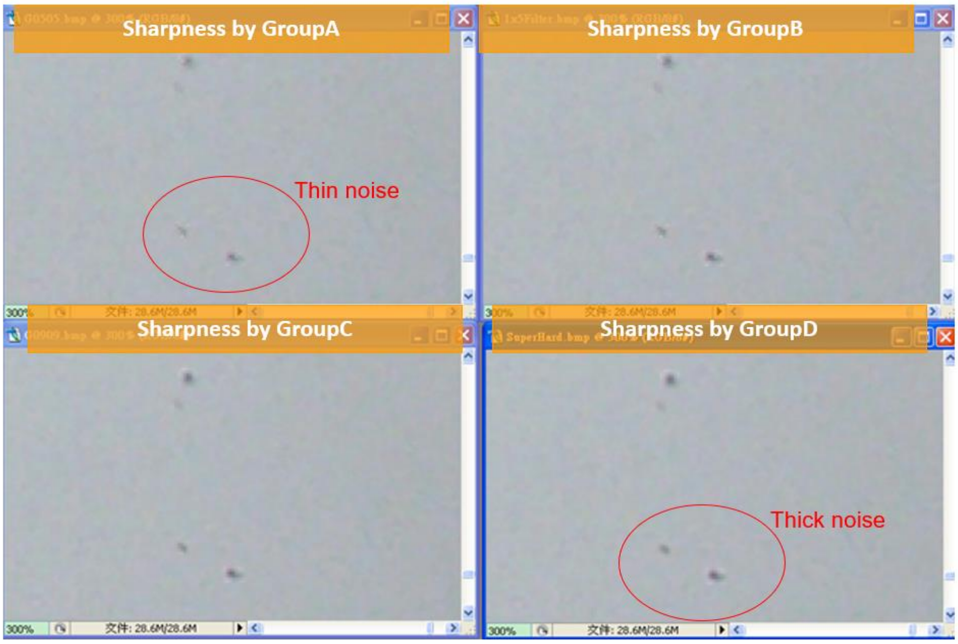


Fig. 5-221 Corresponding result by example setting

For texture, somewhat higher variance sharpness help let texture look natural, therefore, groupB is better than group D.

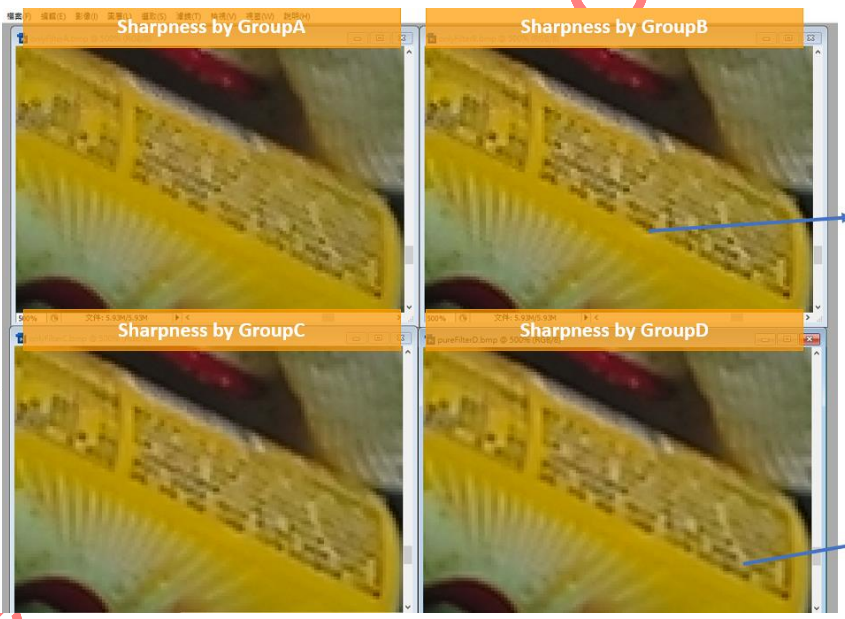


Fig. 5-222 Corresponding result by example setting

■ Suggested setting1: (use all kinds of filter to handle with different feature pixels)

Smooth area's feature value is often less than 5, while hard edge's feature value is often larger than 25 in past experience. For feature value locates in 5~25, Group B, C can handle with them. (mainly for soft texture ~ strong texture) For smooth area, since only using GroupA, even enhancing somewhat noise, noise still looks thin. (not thick style). For hard edge, GroupD is used to let hard edge look uniform and smooth.

Example: Use four filter groups together

Fig. 5-223 example of filter threshold setting

- Suggested setting 2: (enhance fine texture as higher priority; EX: low iso case)

Use Group B for most of pixels in image; and utilize Group C to help keep hard edge's smooth.

Example:

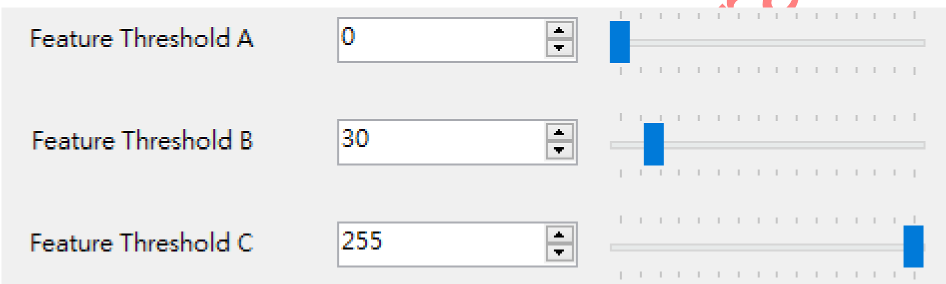


Fig. 5-224 example of filter threshold setting

- Suggested setting 3: (protect edge smooth as highest priority in high iso case)

For high iso, often tune conservative sharpness and also need to prevent from ugly strong edge; Mainly use Group D to help achieve this style

Example:

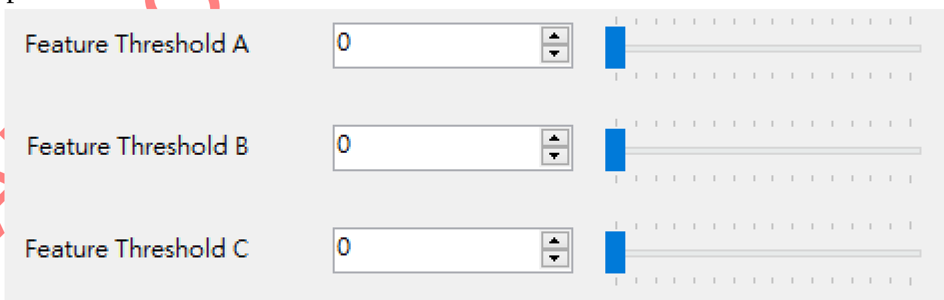


Fig. 5-225 example of filter threshold setting

5.15.5. Tunings for "Laplacian" sub-page

For this sub-page, sharpness enhancement value can be adjusted depending on preference.

- For positive value & negative value of sharpness enhancement, adjusting their response curves
- Image center and corner can set difference response curves for reducing corner blur causing from lens (EX: let corner response curve have higher value than center response curve)

Lens may cause image corner blur, example is shown:

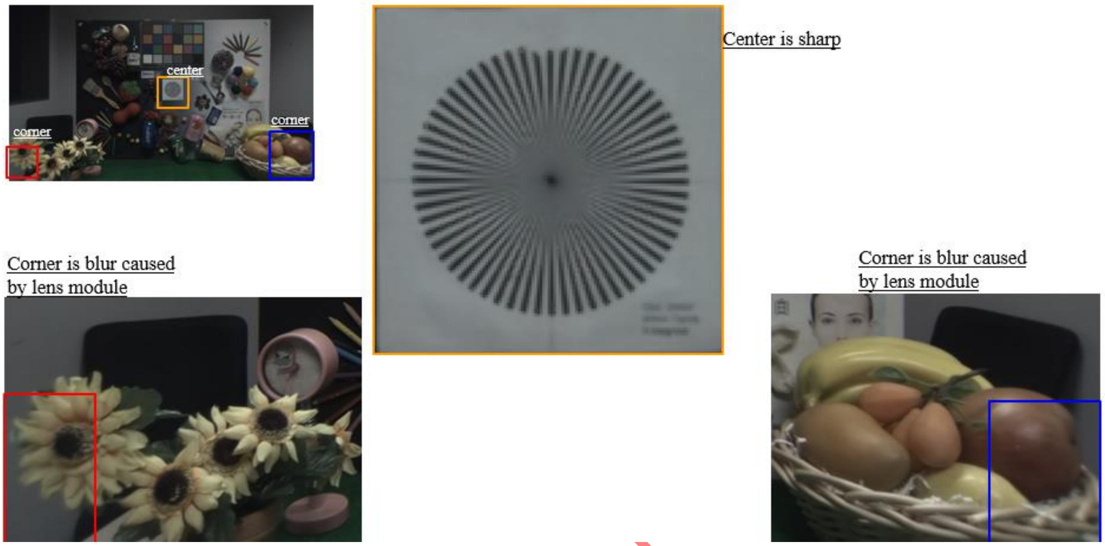
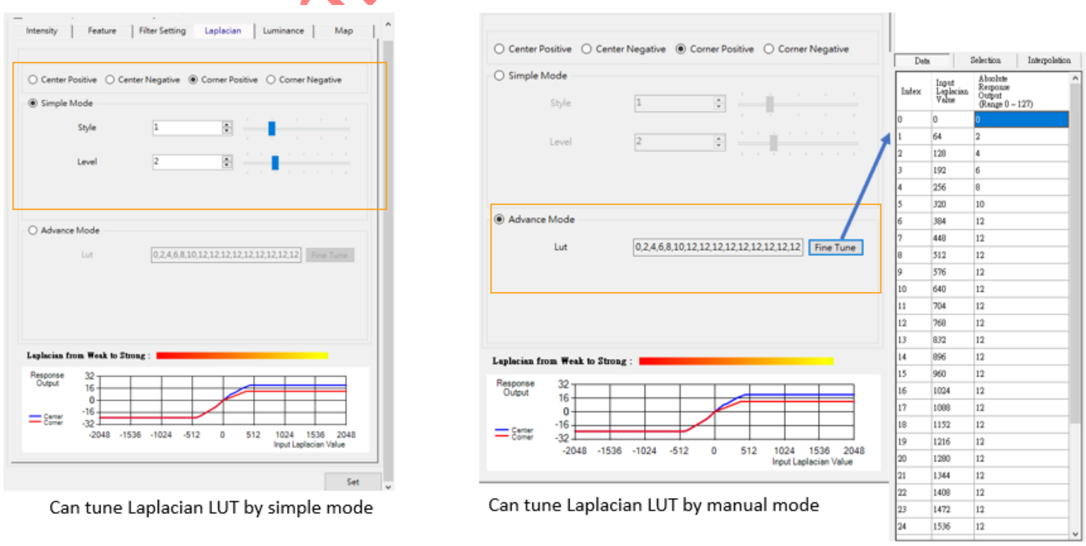


Fig. 5-226 Lens causes image corner blur

To compensate it, user can let image corner pixel adopting relative aggressive sharpness than image center. Four curves need to be tuned: center positive, center negative, corner positive, corner negative. Two different tuning method is shown below:



X axis: input response value
Y axis: output mapping response value

Fig. 5-227 Two methods for Laplacian value tuning

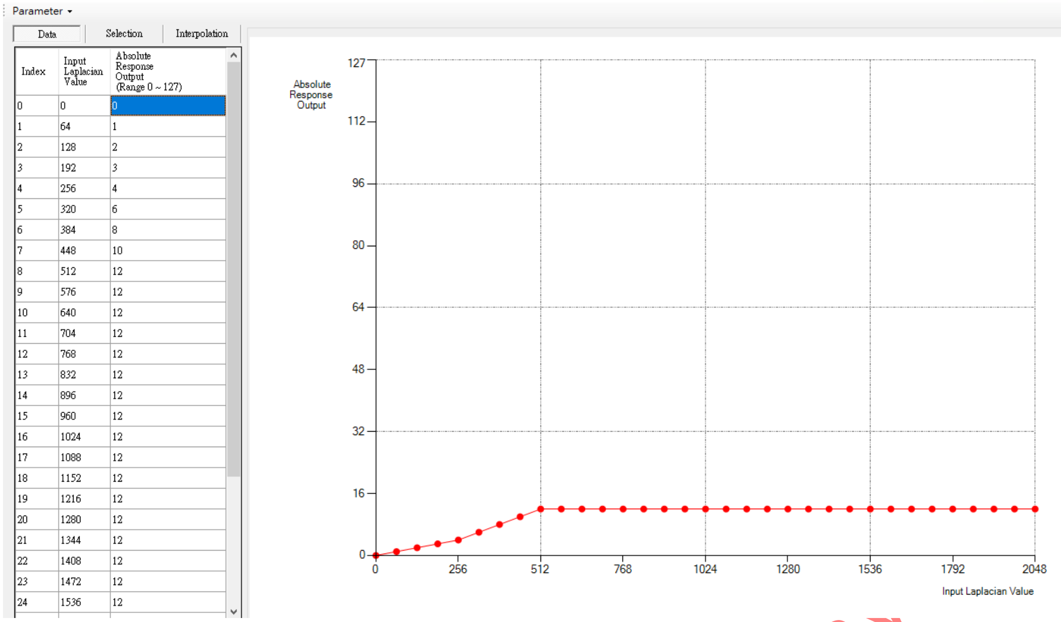


Fig. 5-228 Description for Laplacian response curve

In this curve:

- X –Axis: input Laplacian value
- Y – Axis: desired response

User can tune it to determine positive halo & negative halo response amount; center response & corner response amount can also be different. From low response to high response, curve is divided by 33 end points, mapping to Laplacian value of 0, 64, 128, 192…..2048. For each Laplacian value end point, user can set desired response value, data range is 0~127. Higher value means higher corresponding response for sharpness preference. Because that Laplacian value may be negative, when tuning negative curve, the value show on UI will be noted as negative value.

Tuning example is shown below:

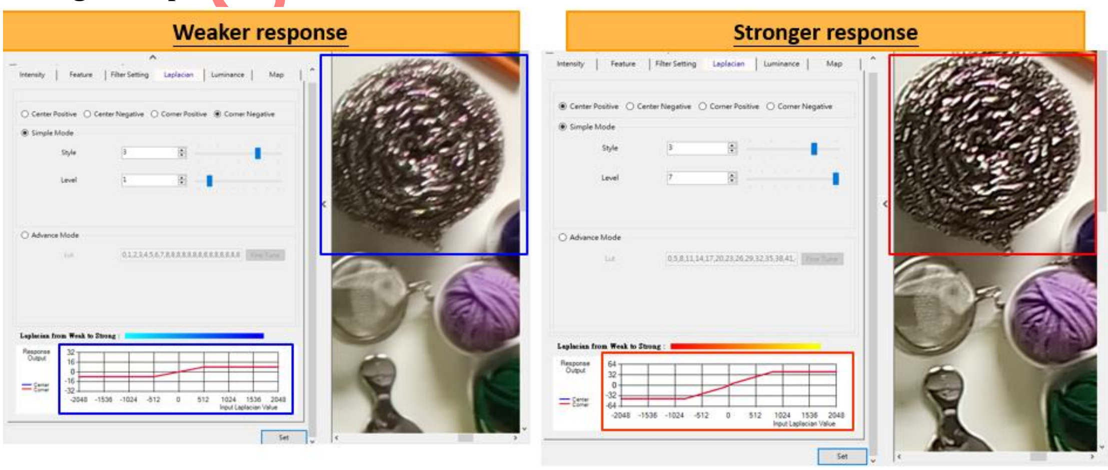


Fig. 5-229 Example of Laplacian value tuning

Suggested settings for Laplacian curve:

1. Smooth increasing from zero to a desired strength (EX: 10~20 at end)
2. Final strength is suggested to be less than 20 to avoid too obvious halo

General suggested setting is shown in below figure:

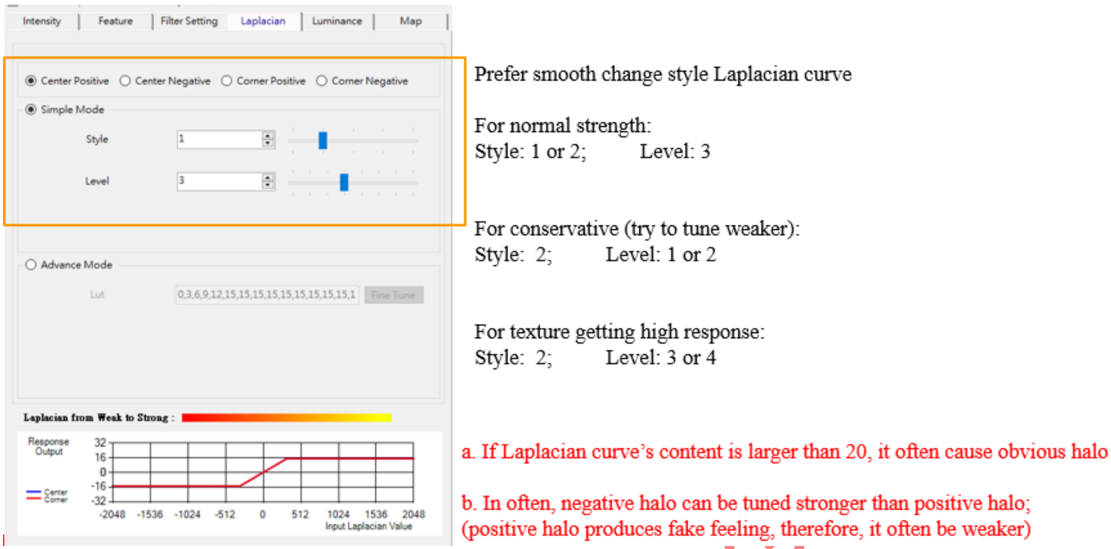


Fig. 5-230 Suggestion of Laplacian curve tuning

5.15.6. Tunings for "Luminance" sub-page

For each pixel, user can tune overshooting control by two factors, called it as alpha1 & alpha2;

- alpha1:
  - ☐ references from pixel intensity, in high luminance area or dark area, sharpness level can be further reduced or amplified by alpha1.
  - ☐ Tuning method:

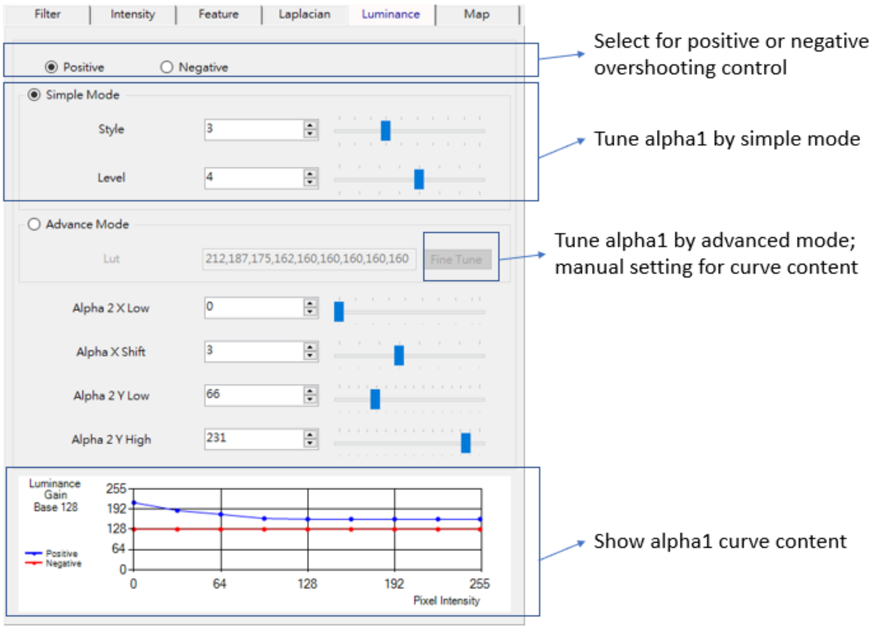


Fig. 5-231 Icons for tuning Alpha1

1. Both of positive & negative shooting control need to be tuned individually
2. User can use simple mode tuning or set curve content by advanced mode.
3. There are 9 end points mapping to corresponding luminance value as below figure:

Input Intensity	Mapping output luminance gain
0	Element1
32	Element2
64	Element3
96	Element4
128	Element5
160	Element6
192	Element7
224	Element8
256	Element9

Fig. 5-232 End points for Alpha1 Curve

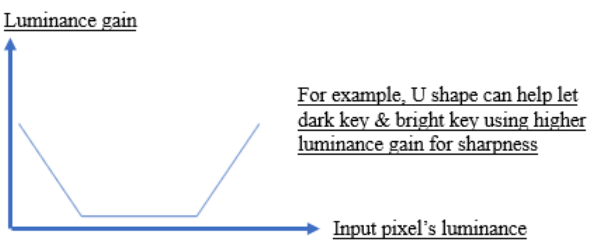


Fig. 5-233 meaning of Alpha1 curve

Tuning example if shown below:

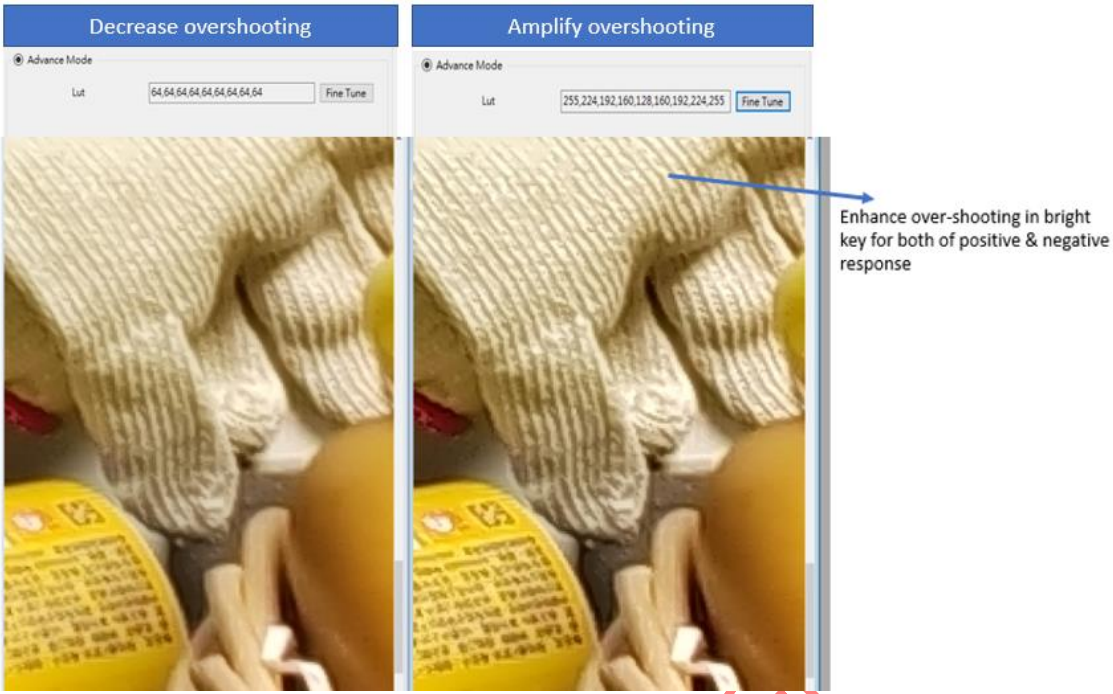


Fig. 5-234 Tuning example of luminance shooting control

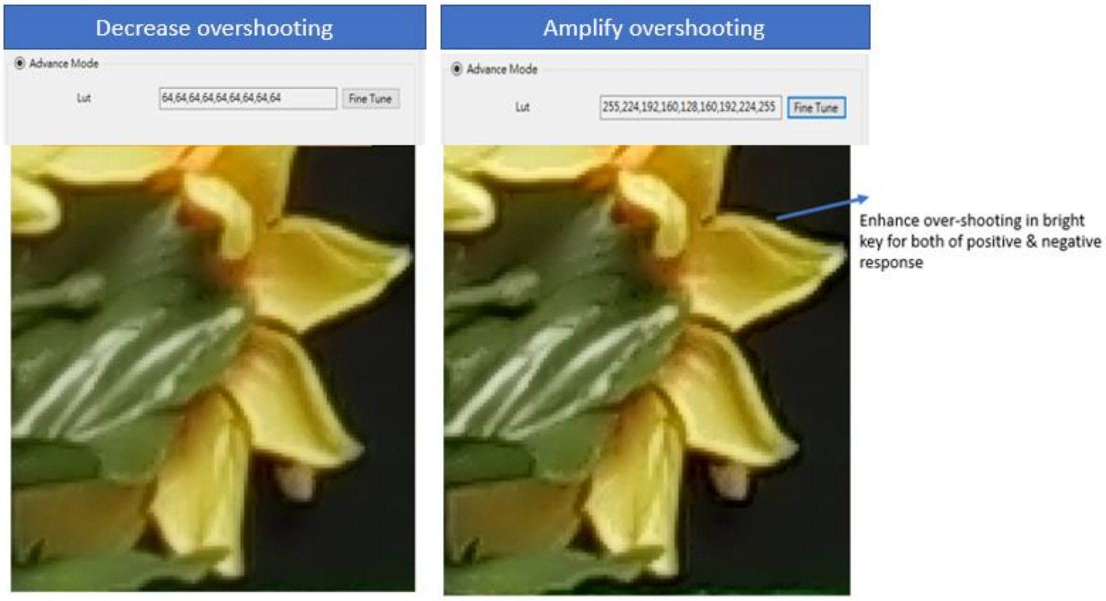


Fig. 5-235 Tuning example of luminance shooting control

Suggestion for tuning:
1. Usually, dark key & high key can put relative stronger shooting; (U shape)
2. Another usual using method:
 → Bypass this preference, just let each element be 128

■ alpha2:

- reference from absolute response amount, doing overshooting control according to current response value. Idea is shown below:

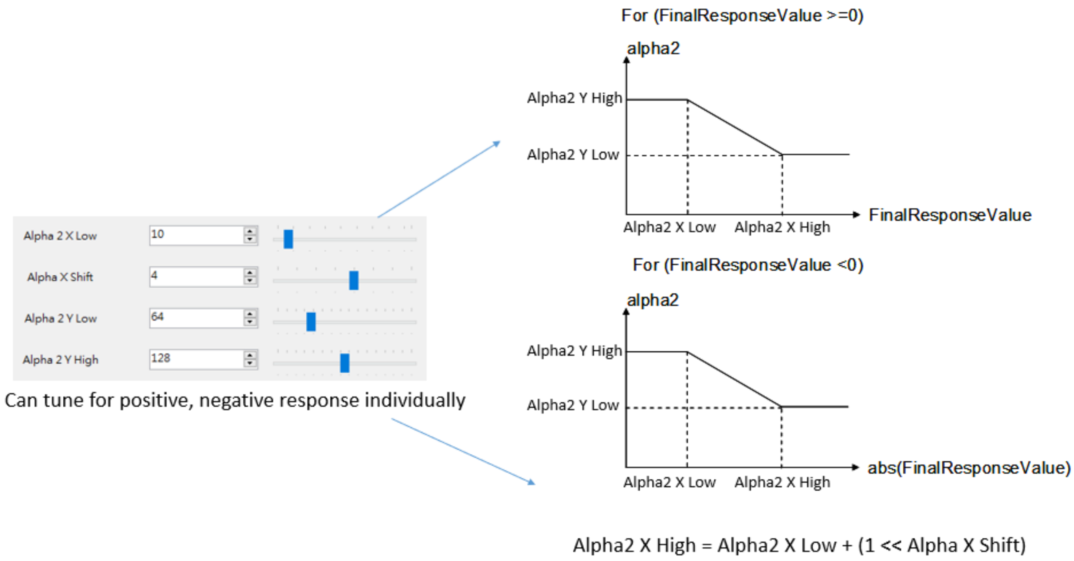


Fig. 5-236 Concept of alpha2 setting

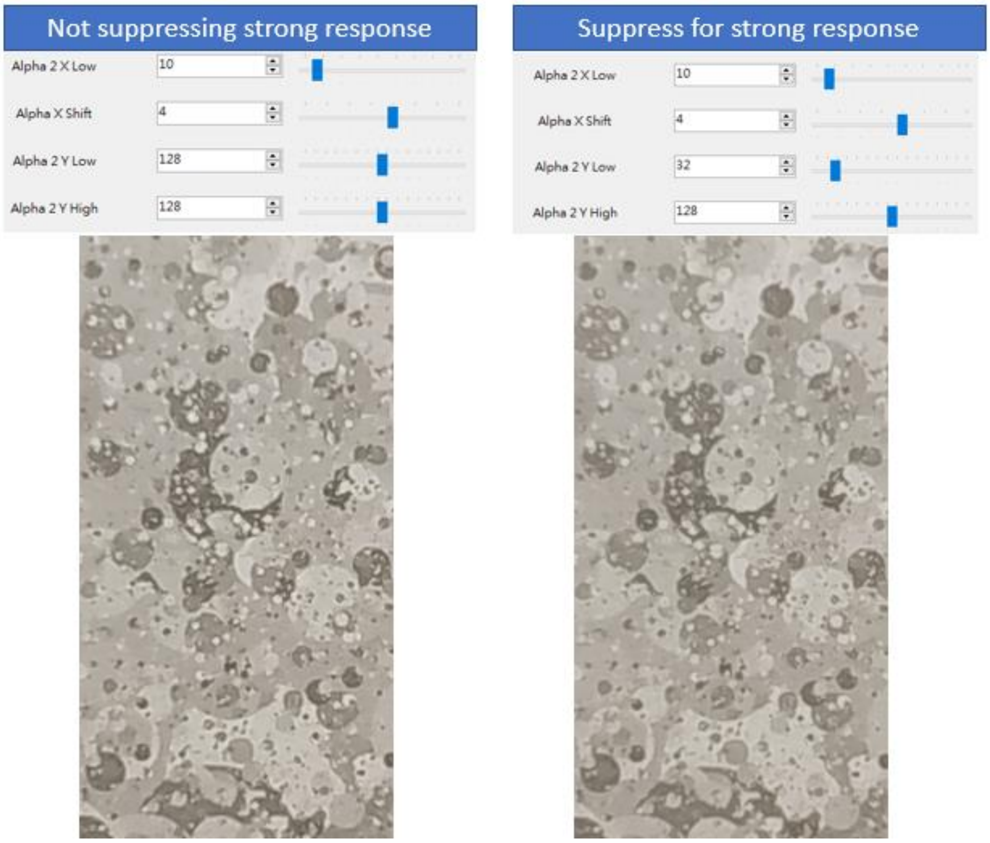


Fig. 5-237 Example of alpha2 tuning

Using Alpha2 X Low & Alpha X Shift to determine the response region for suppression, later, using Alpha2 Y High, Alpha2 Y Low to determine the response decreasing amount.

At last, sharpness overshooting control factor will be determined by mean value of alpha1 & alpha2. Both of alpha1 & alpha2 can be tuned for positive or negative response control individually.

Suggestion for tuning:

→Usually, if no specific purpose, user can just let Alpha2 Y Low & Alpha2 Y High use same value (namely don't want to do suppression by Alpha2); if these two values are lower and using identical value, then it will let shooting control mainly come from Alpha1.

5.15.7. Tunings for "Map" sub-page

Map means corner response's weighting; for below example, right picture's corner part is much bright, it means that image corner will adopt more weighting for corner response curve's content. For an input pixel, it needs to look up center response curve to know the center version sharpness value, it also needs to look up corner response curve to know the corner version sharpness value in section of "Laplacian" curve tuning. At last, by input pixel's map value, do weighting average for center and corner sharpness value to get determined response. If user prefers to let image corner pixel get higher response, at first, needing to let corner curve have higher values, later, needing to tune map as below example's right figure style to let image corner pixel can blend with corner response by higher weighting.

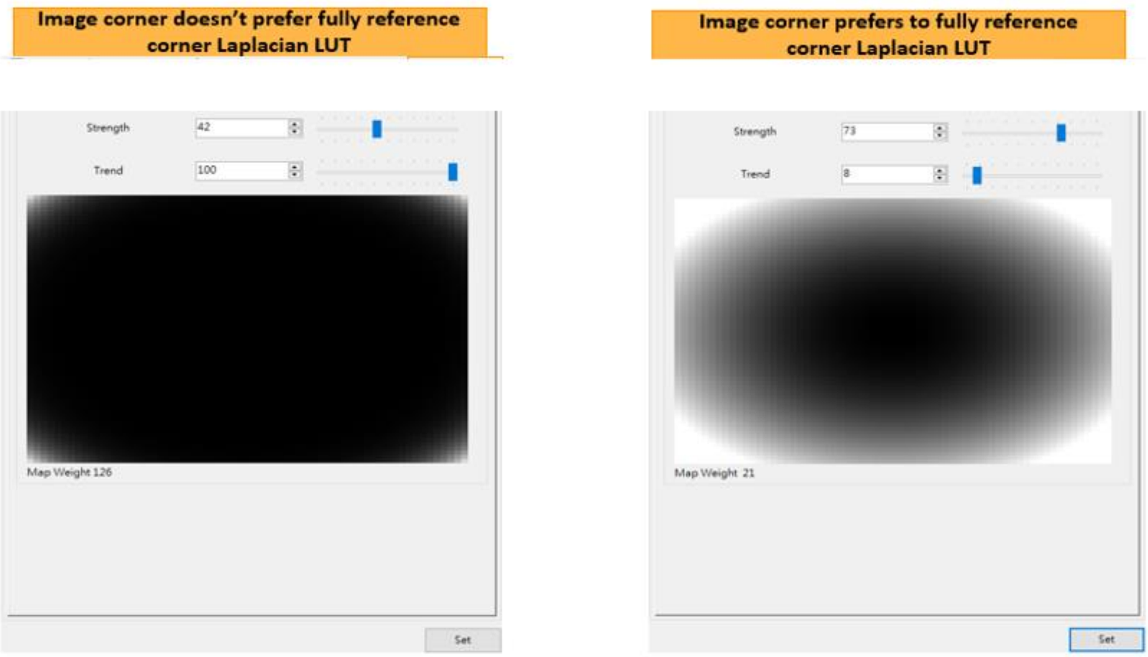


Fig. 5-238 Map tuning example

Choose desired map content by tuning "strength" & "trend" on UI of Map page.

Tuning example is shown below:

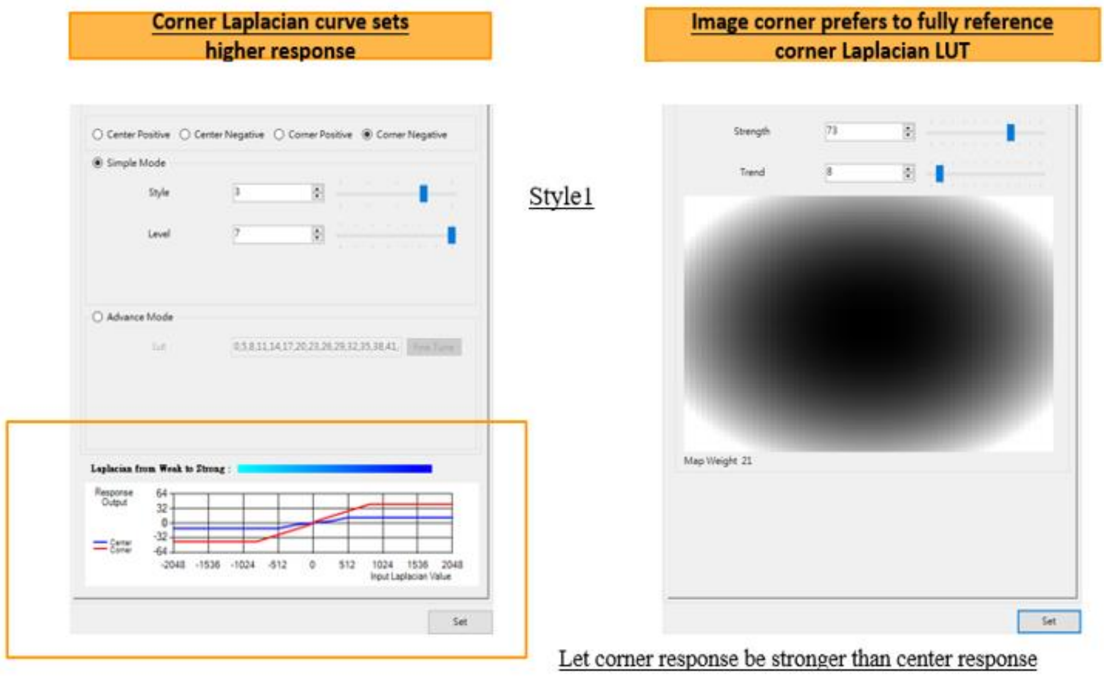


Fig. 5-239 Map tuning example

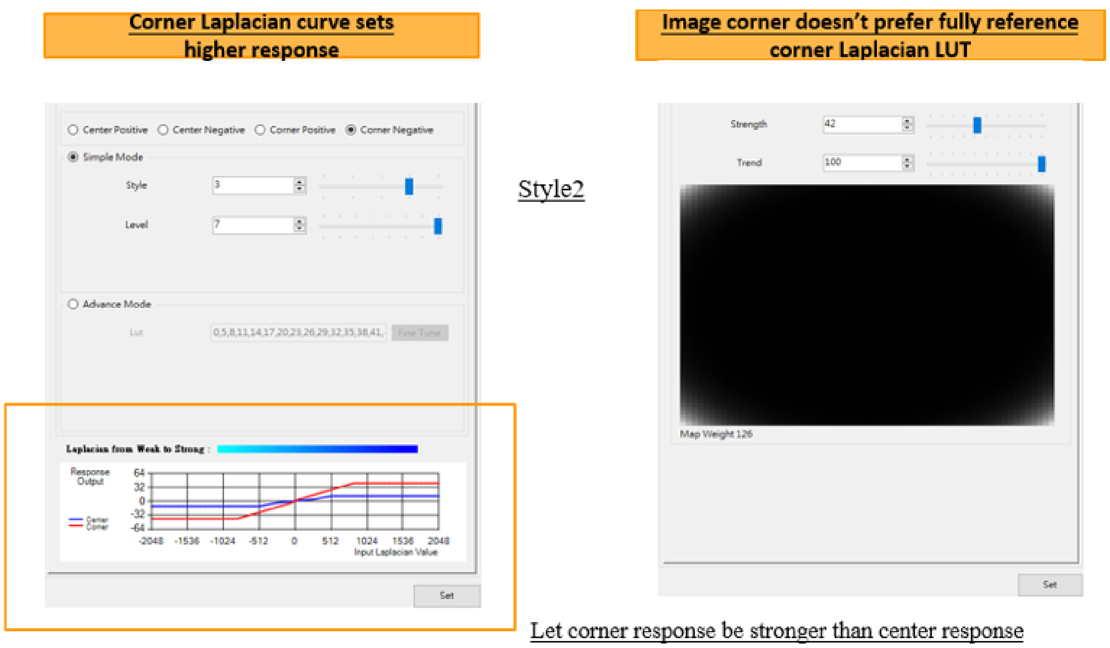


Fig. 5-240 Map tuning example

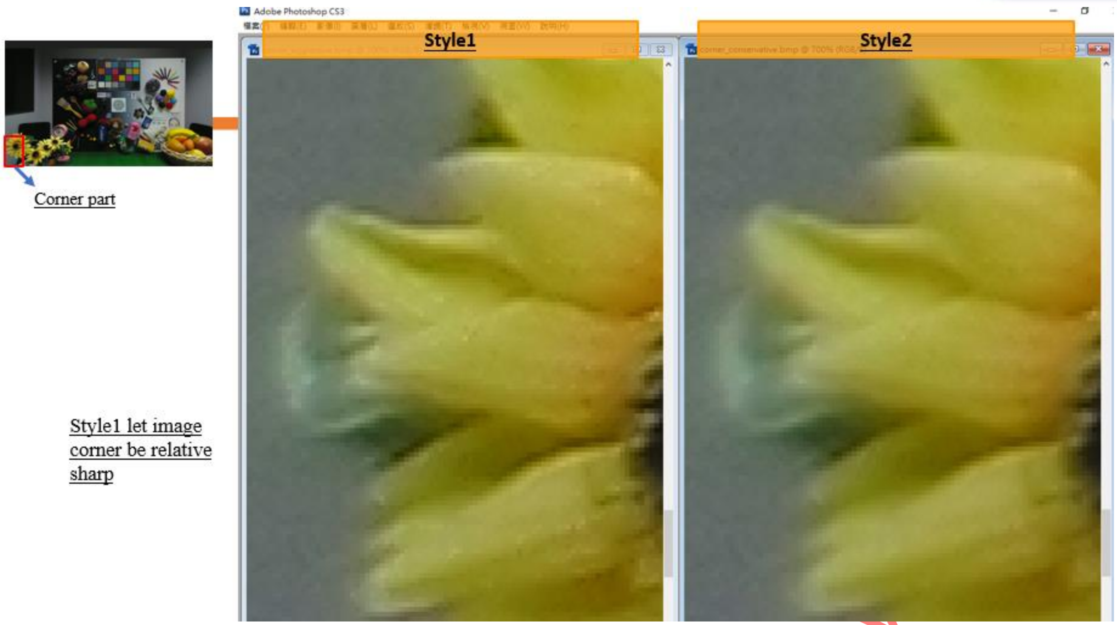


Fig. 5-241 Map tuning example

In order to let user get mapping relationship with input image and map, Help UI is designed, example is shown below:

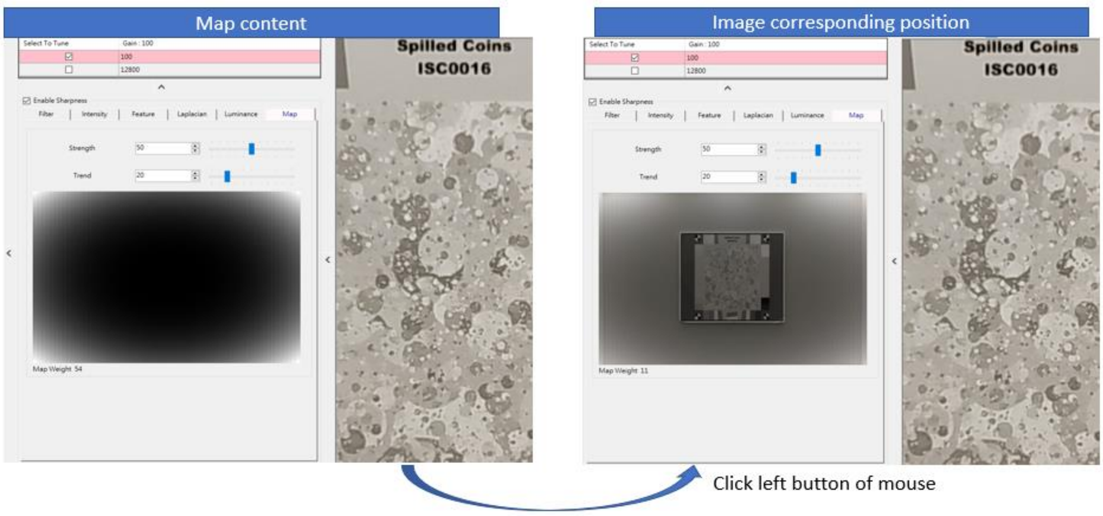
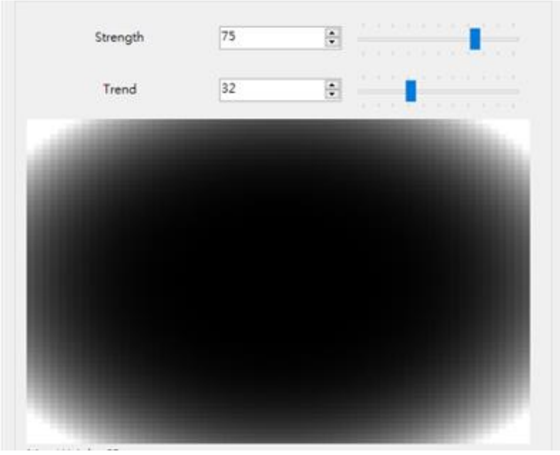


Fig. 5-242 Map tuning example

By referencing image & map relationship, user can reference it to help tune map content.

Suggestion for tuning:

→Usually needing a smooth change style, suggested setting is just like below:



Map style:
Let corner be aggressive than center

Suggestion:

Strength: 75

Trend: 32

Fig. 5-243 Suggested map style – corner be relative aggressive and map is smooth

6. Process a batch of files

There are three kinds of batch run mode in our tool, a) to run consecutive frames b) to run independent frames c) to run independent data. Fig. 6.1

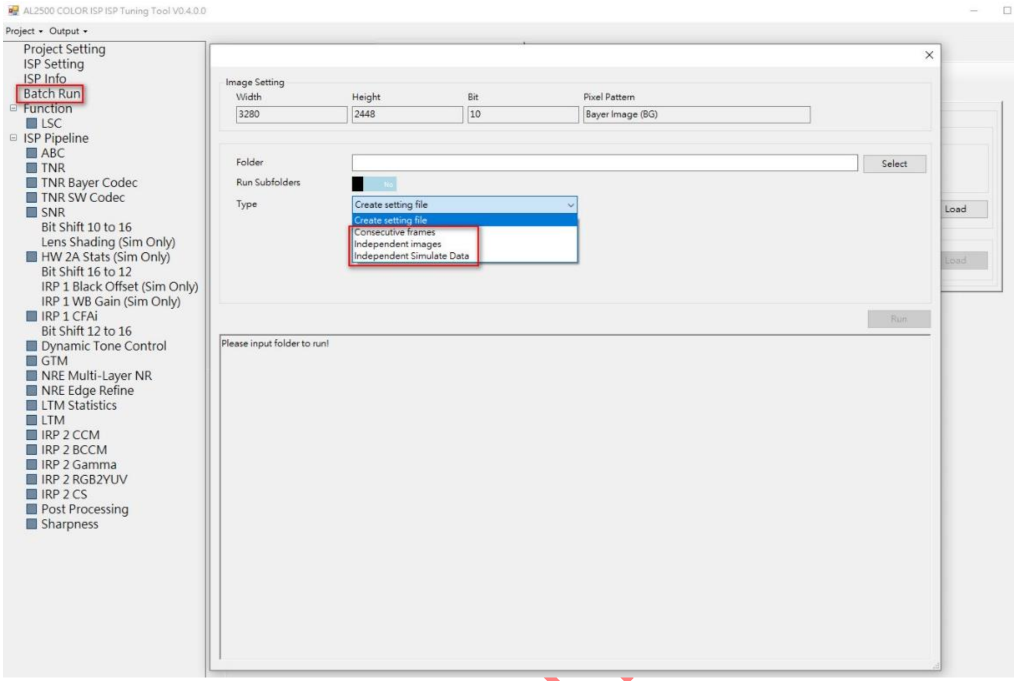


Fig. 6.1 Batch Run page

6.1. Create Setting File

Refer to fig. 6.2, create a folder and put all your images that need to be simulated in it.

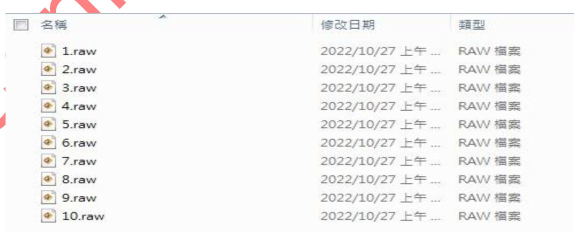


Fig. 6.6-1

And fill image information in condition page from tuning tool.

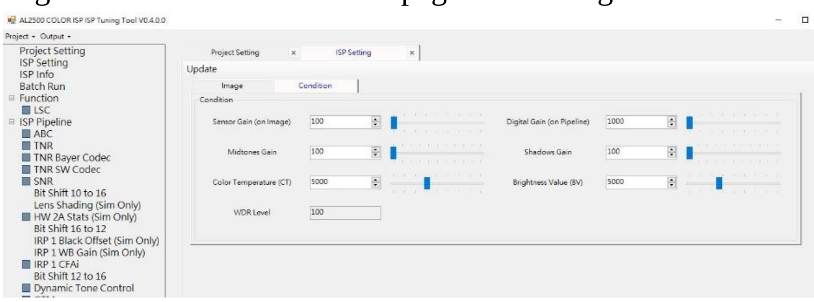


Fig. 6.6-2

Then, fill in the path and push run button. You will get a batch run setting file

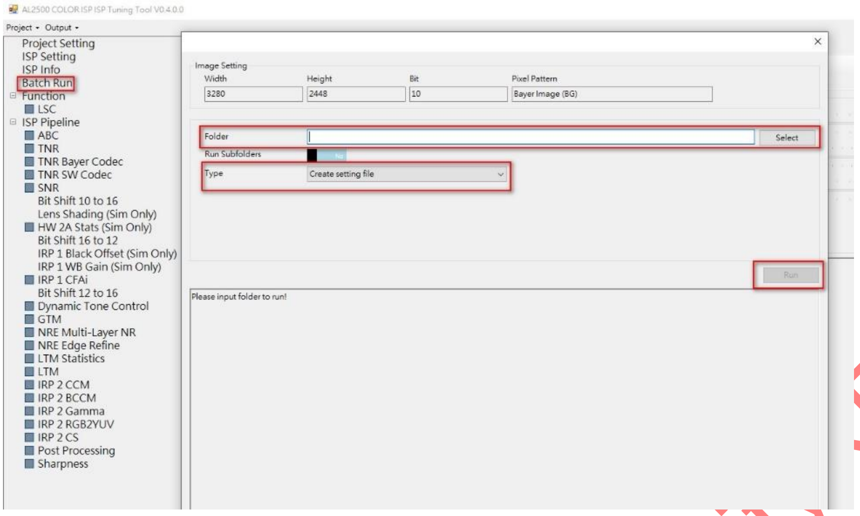
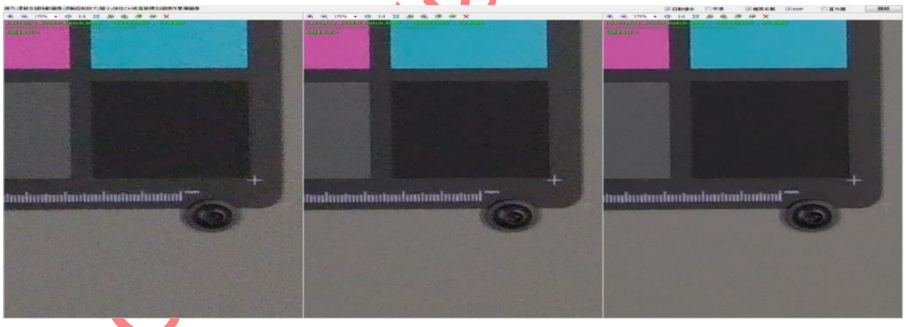


Fig. 6.6-3

6.2. Run Consecutive images and Independent Images

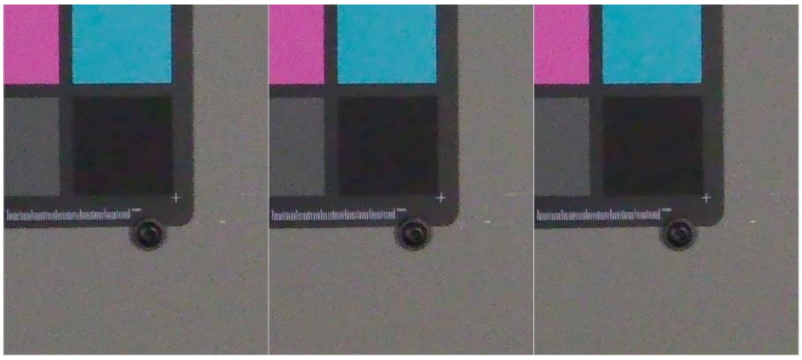
If you want to run TNR function and reference previous frame, you have to choose consecutive images mode. Because it will reference previous fame, it will have cleaner image, refer to fig. 6.5, compared to independent images.



Frame 2 Frame 5 Frame 10

Fig. 6.6-4

Refer to fig. 6.6, if you do not want to reference previous frame's TNR result, you can choose independent images. Because it won't reference previous fame, it will have noisier image compared to consecutive images.



Frame 2　　Frame 5　　Frame 10

Fig. 6.6-5

6.3. Run Independent simulate data

Refer to fig. 6.7, If you want to tune functions after TNR, you have to generate simulate data at first. Choose simulate data check box and run batch file.

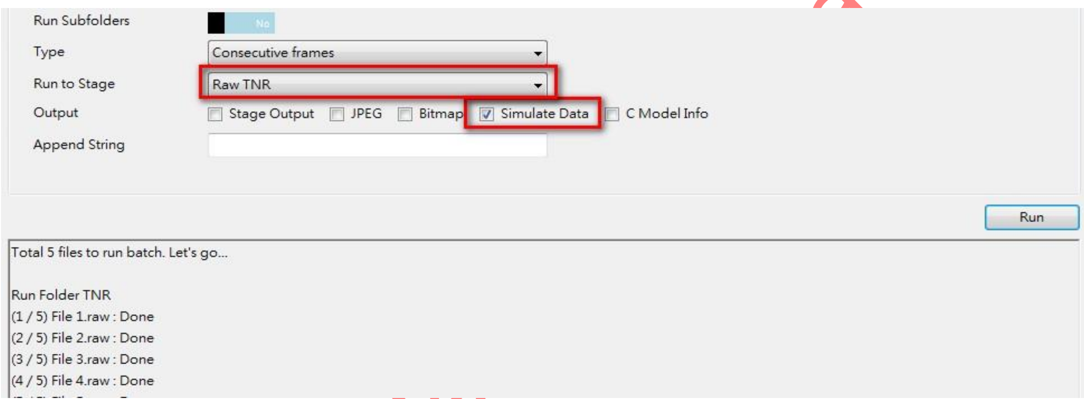


Fig. 6.6-6

Load simulation data path and then choose independent simulation data. Press "run" button to see batch run results.

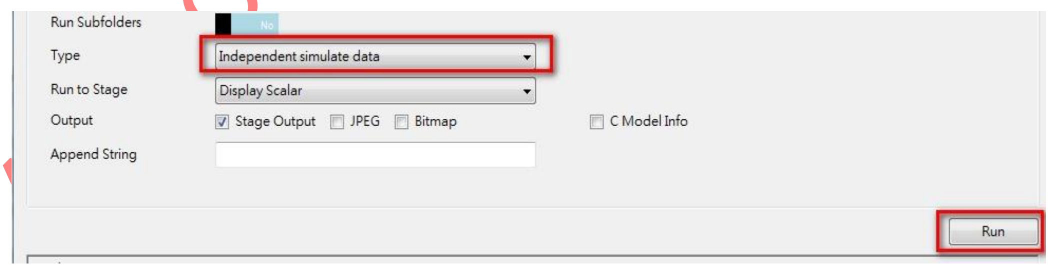


Fig. 6.6-7

6.4. Generate Stage Output

We can choose to run stage output through batch run. First, choose batch run mode. Then, choose pipeline stage output.

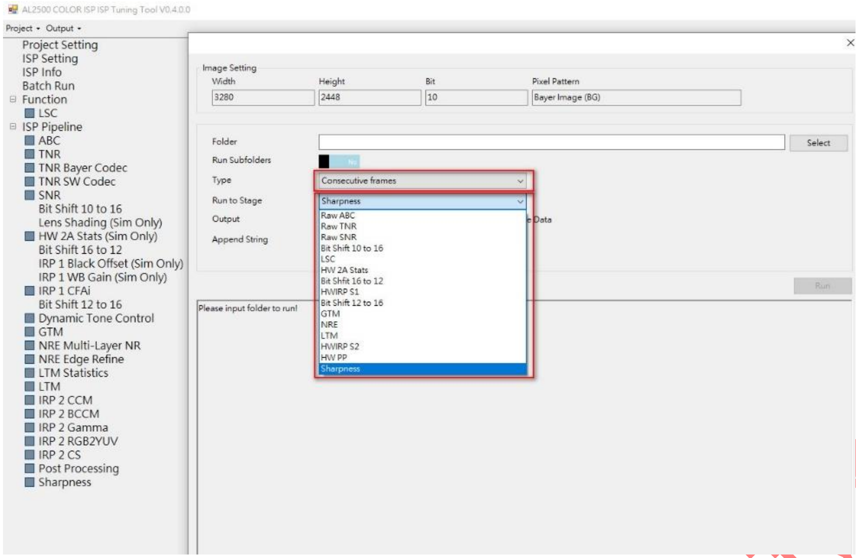

AL2500 COLOR ISP ISP Tuning Tool V0.4.0.0
Project
Output
Project Setting
ISP Setting
ISP Info
Batch Run
Function
LSC
ISP Pipeline
ABC
TNR
TNR Bayer Codec
TNR SW Codec
SNR
Bit Shift 10 to 16
Lens Shading (Sim Only)
HW 2A Stats (Sim Only)
Bit Shift 16 to 12
IRP 1 Black Offset (Sim Only)
IRP 1 WB Gain (Sim Only)
IRP 1 CFAi
Bit Shift 12 to 16
Dynamic Tone Control
GTM
NRE Multi-Layer NR
NRE Edge Refine
LTM Statistics
LTM
IRP 2 CCM
IRP 2 BCCM
IRP 2 Gamma
IRP 2 RGB2YUV
IRP 2 CS
Post Processing
Sharpness
Image Setting
Width
Height
Bit
Pixel Pattern
3280
2448
10
Bayer Image (BG)
Folder
Select
Run Subfolders
Type
Consecutive frames
Run to Stage
Sharpness
Output
Append String
Raw ABC
Raw TNR
Raw SNR
Bit Shift 10 to 16
LSC
HW 2A Stats
Bit Shfit 16 to 12
HWIRP S1
Bit Shift 12 to 16
GTM
NRE
LTM
HWIRP S2
HW PP
Sharpness
Run
Please input folder to run!

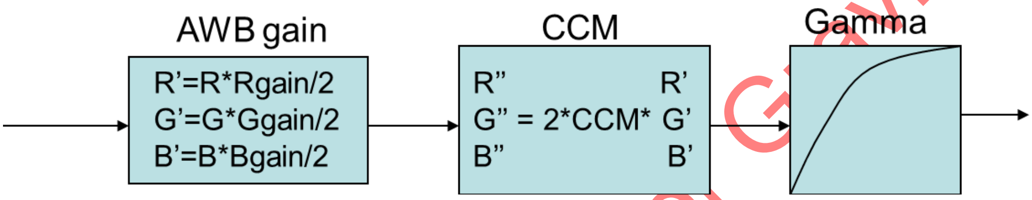
Fig. 6.6-8

- **Appendix**

Improvement for color tint (face case)

The function which is related to "Clip level", "Protect range" and "CCM decimal" registers have not been used in GXR. We use more advanced GTM/LTM instead of this old function. Currently, only default setting in tuning tool can work normally. Please just use default setting in tuning tool. We just do a previous case study by register setting to describe this idea, an example setting is shown below: (set by register setting to do simulation)

- ☐ Color protection idea:
  To preserve WB gain 1bit for CCM usage; basic idea is to prevent from over-saturation in WB gain stage, therefore, only applying half strength WB gain, at last, apply double strength CCM later.



  Therefore, a possible method is to apply half AWB gain to keep information not too over-saturated, later, applying color protection logics and compensate by double CCM strength.

- ☐ Example case:

	Case1 (1x)	Case2 (0.5x)
r gain	423	212
g gain	256	128
b gain	383	192

Case1:
awb_gain_r = 12'h1A7
awb_gain_gr = 12'h100
awb_gain_b = 12'h17F
awb_gain_gb = 12'h100

Case2:
awb_gain_r = 12'hd4
awb_gain_gr = 12'h80
awb_gain_b = 12'hc0
awb_gain_gb = 12'h80

For Case1, color information may loss after WB gain. For Case2, in WB stage, just using half strength. Later, starting to use the setting and double strength CCM as below:

(Settings in register)

	Case1	Case2
clip_level	12'hfff	12'f7ff
protect_range	3	3
ccm_decimal	1	0

“clip_level” is lower in Case2, it aims to let color protection start to work for lower pixel intensity pixels and “ccm_decimal” is set as 0 (meaning: using double CCM strength with respect to Case1).

Results are shown below:

Case1

Case2

We can see that the Case2 keeps more details at very high brightness face.