ITU-R BT.2124 Objective Color Metrics Measurement Using Vooya Video Player HDR Chroma Grapher Plug-In

In Single-Master UHD HDR-SDR Production and Transmission

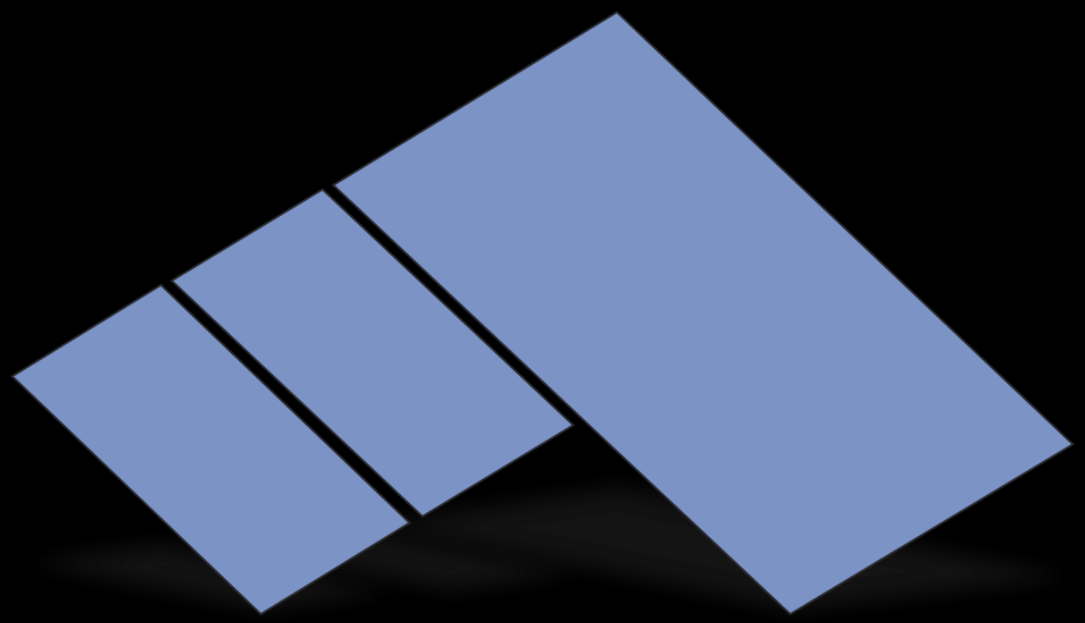
UHD HDR-SDR Objective Color Metrics Testing

This eBook will evolve as we document the complete workflow.

Lesson Four reviews Objective Color Metrics Testing.

It is provided as a reference for broadcast teams.

Apple Book Store Link is here:
http://books.apple.com/us/book/id6443519839



Lesson 3

HDR/SDR Objective Color Metrics Measurement using Vooya Video Player

Making sure your pipeline is accurate

Tools Description

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List of Tools and Patterns

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How to gather test data

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Plotting

Software and Test Patterns Required

Software

- Vooya Video Player ($29.99)
  - Vooya Chroma Grapher - Measures values and converts them to ITP, y'u'v, nits ($70/year)
- Apple Numbers Spreadsheet
  - Click to download reference plotting spreadsheets

Test Patterns

- BT.2111 Fancy Bars - Evaluate basic levels using conventional vector scope and waveform
- Sarnoff Test Pattern: Yellow Brick Road
  - HLG BT.2100 Scene-Referred
  - PQ BT.2100
  - SDR BT.709 Condensed 2m-123IRE

The purpose of Objective Color Metric Measurement?

Many current image measurement metrics are tailored around measuring luma difference but not color volume accuracy.

Additionally, many current metrics are not specifically designed for HDR and SDR.

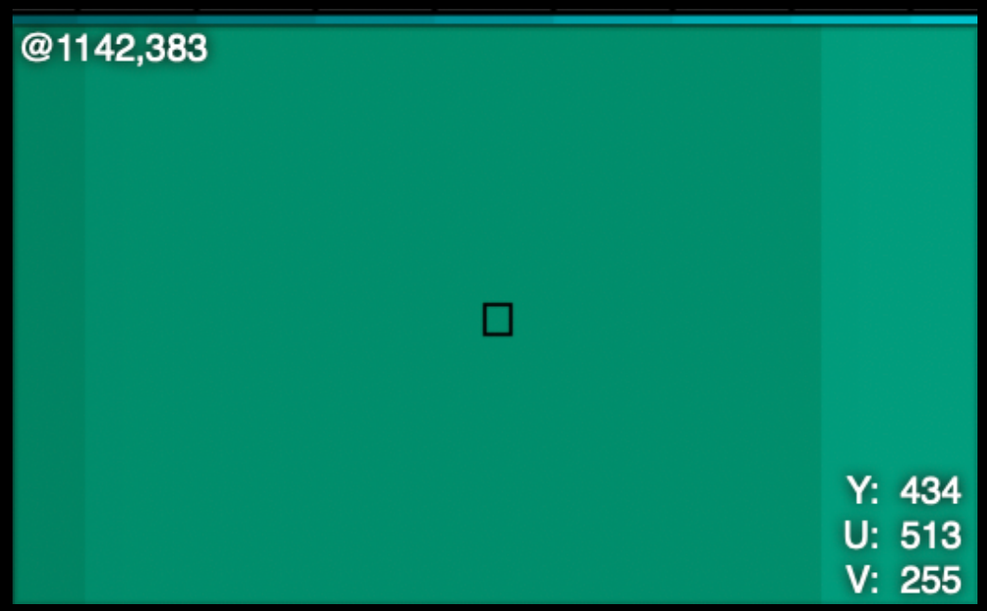
These sets of tools convert all signal formats into a single color-representation known as ITP where “I” is intensity and T/P represent color using a perceptual model and constant hue. The ability to see hue divergency is improved.

The color volume difference metric we use is documented in Recommendation ITU-R BT.2124

Applications Required for Plotting

- **Basic T/P Plotting within Vooya**
  - **Vooya Video Player: Install in “Applications Folder”**
    - **Chroma Metric Plug-in: Install in Vooya Plug-Ins folder (typically in users home folder)**
    - **Simple T/P plotting internal to Vooya only works if Python and dependencies are installed (See Annex)**
- **Sophisticated Plotting Outside of Vooya**
  - **Apple Numbers templates have been built and allow very sophisticated plotting by copy/pasting results from Vooya into a spreadsheet**
  - **Click here for spreadsheet templates**

Define pixel coordinates to measure using Vooya



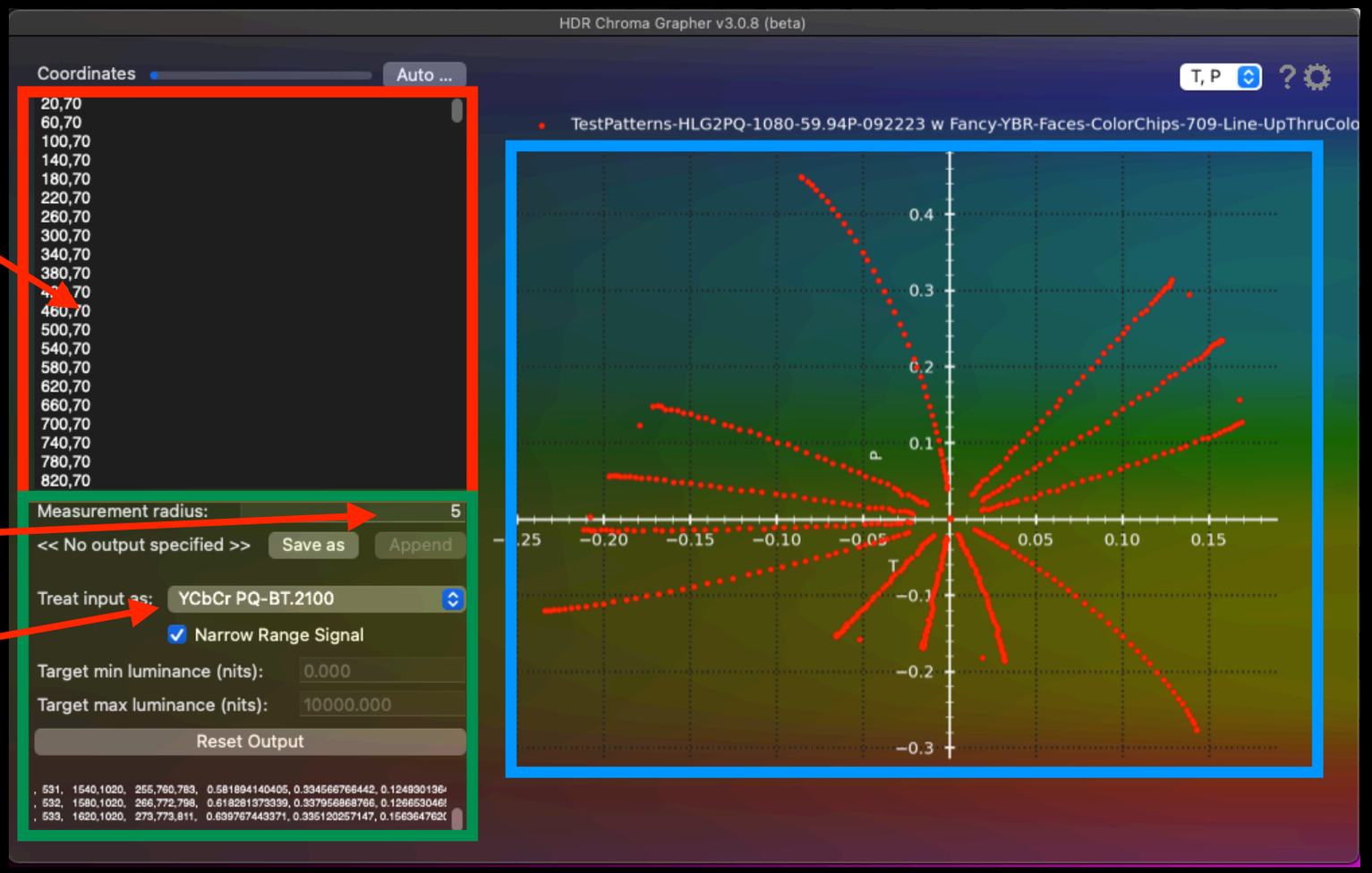
1. Open movie in Vooya
   - Enable “Magnifier” tool
   - Drag “Magnifier” over the test pattern to gather pixel locations that are to be tested and save all coordinates to a comma-delimited (csv) list in a text file.
2. Each x,y pixel location should be on a separate line (use a carriage return between each entry).
3. Store csv text files for future use. Full value list will be copy/pasted into Vooya Chroma Metric plugin window.
   - A pre-built list of coordinates files have been created for Sarnoff Yellow Brick Road patterns located here: CLICK in the resources folder.

Introduction: Chroma Metric Vooya Plug-In

csv coordinates are pasted here

Radius around center point to average results from

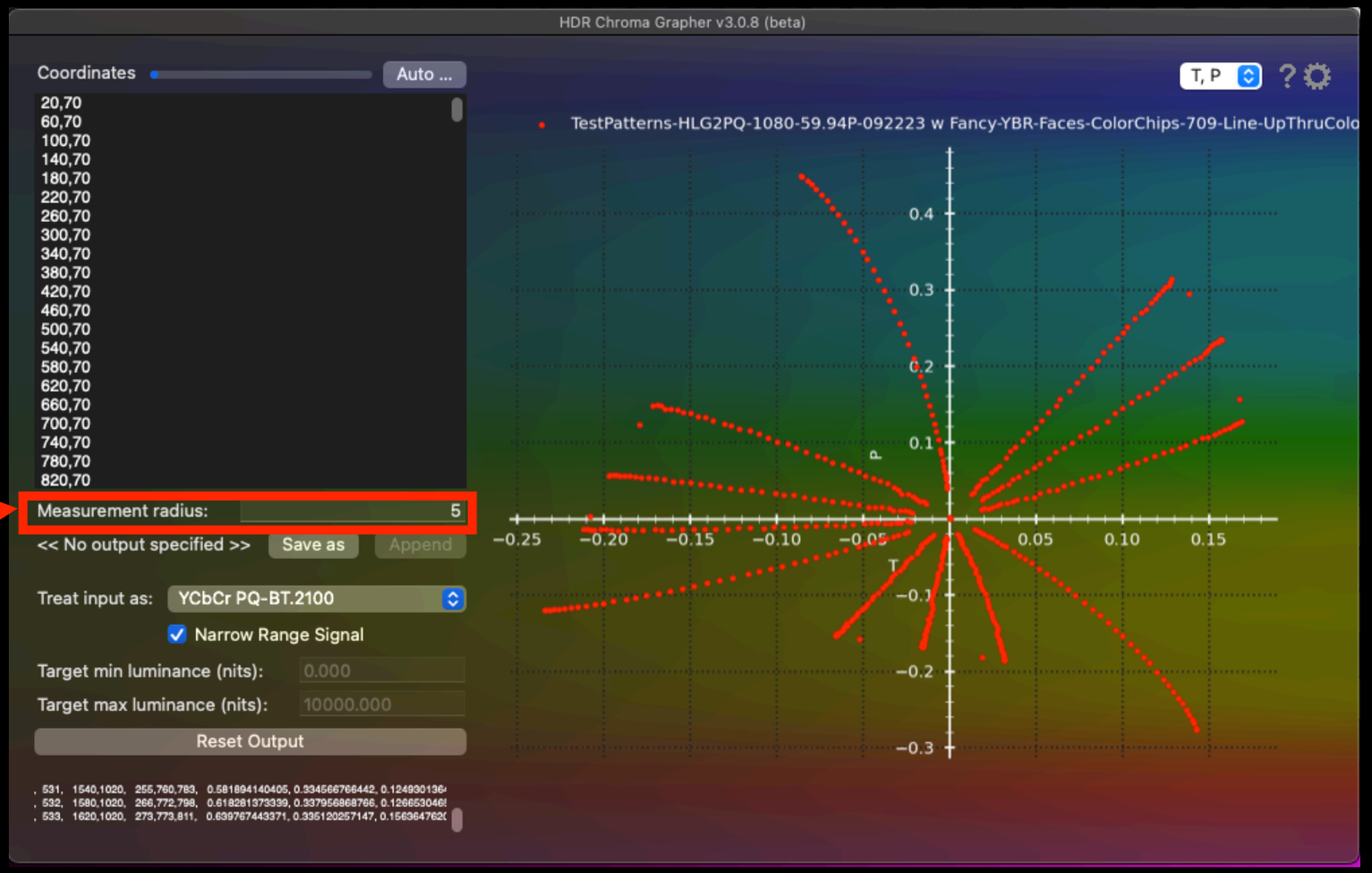
Video format to be measured



1. Red Box = CSV pixel locations to measure Y’CbCr values from video image.
2. Green Box = Set signal format, peak luminance, signal range
3. Blue Box = T/P (from ITP) color plot for checking hue diversions
    - Requires the installation of Python and dependencies (see Annex)

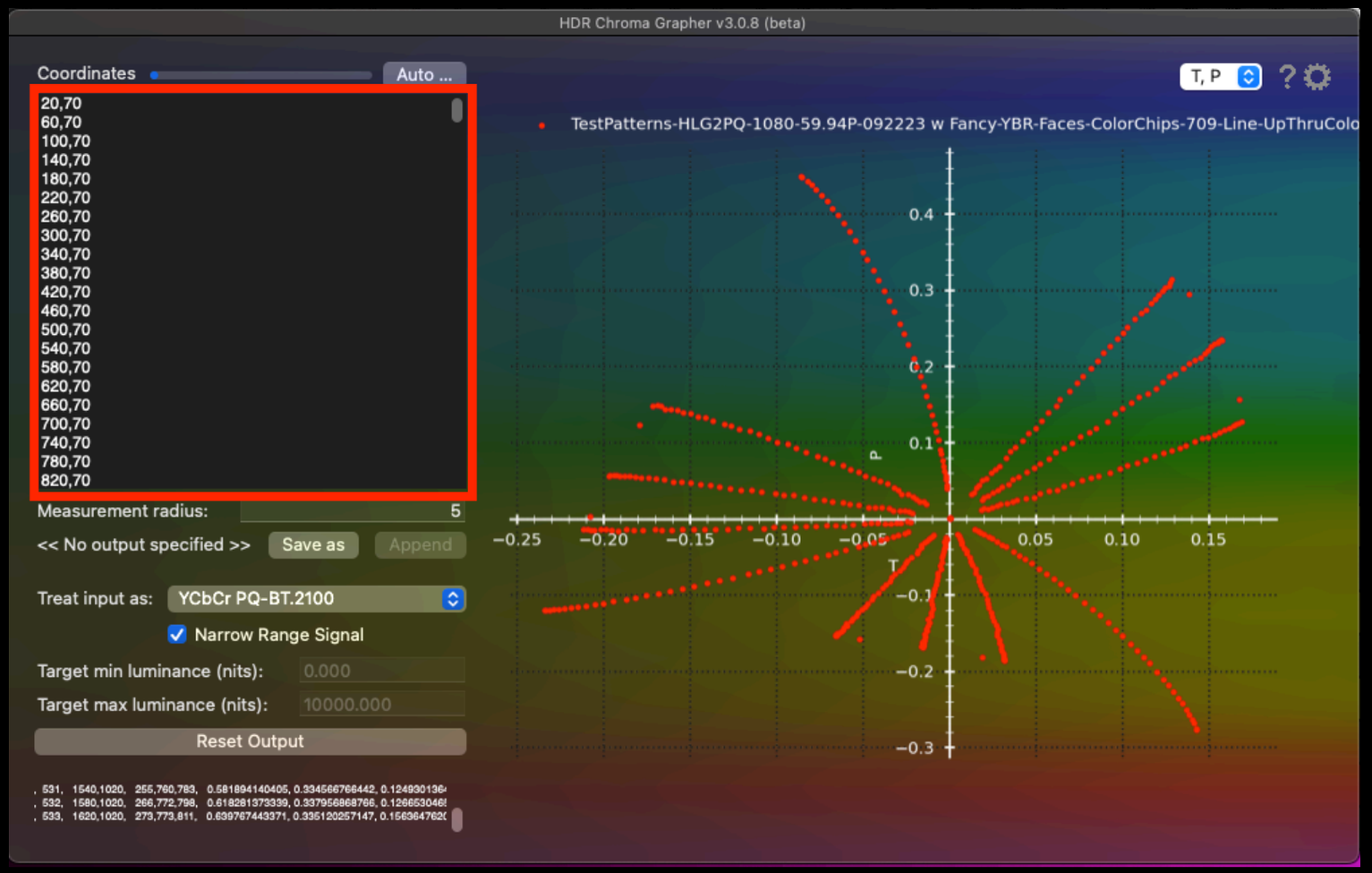
Measurement Radius

Radius around center point to average results from



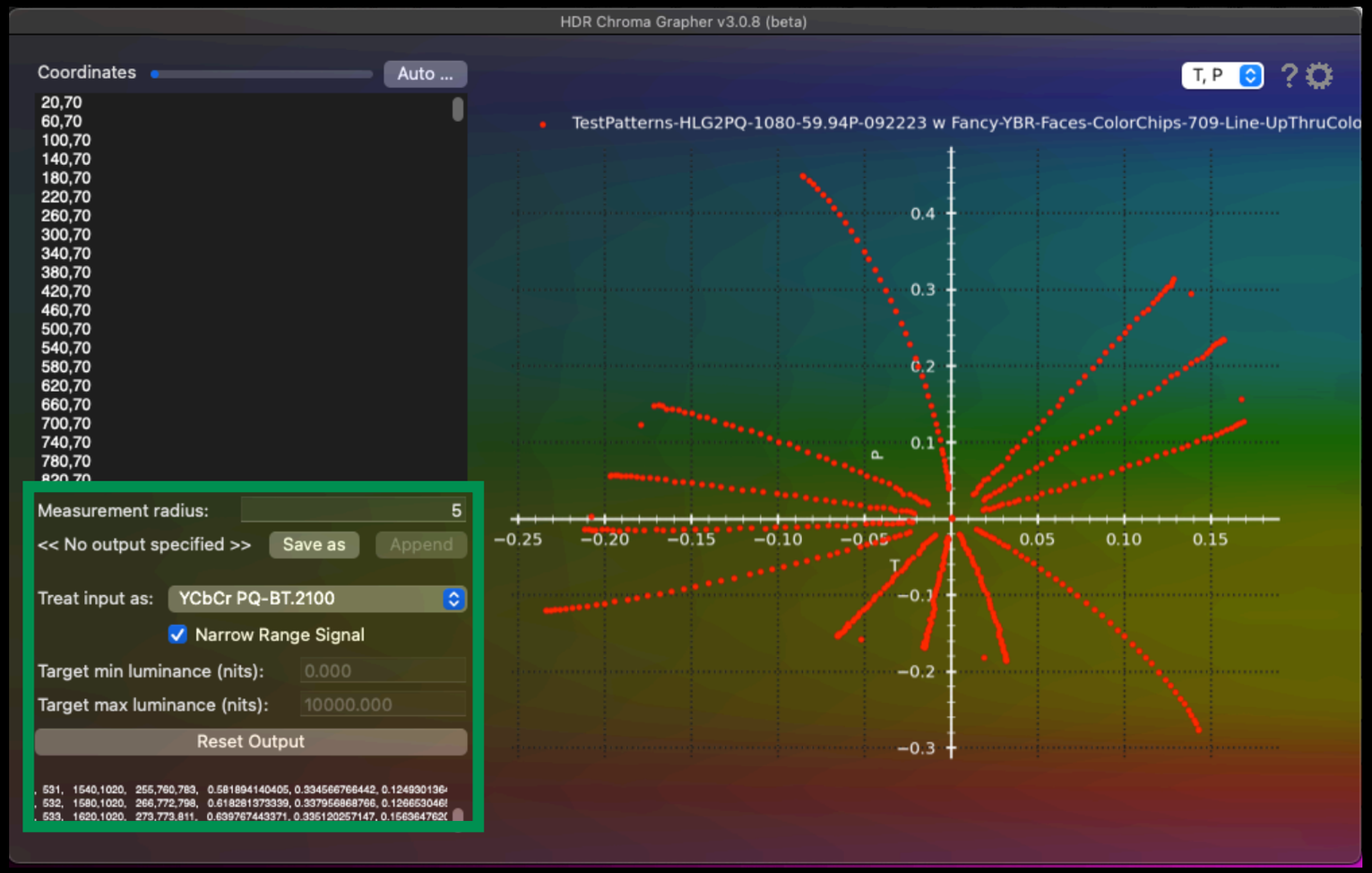
1. Measurement Radius adds a new function to gather average/max stats.
2. A value of “0” will just grab the value of a the single pixel indicated.
3. Each additional value will expand in a circular manner around the center point, measure all the pixels and then calculate average and max error values.
4. This function is beneficial for measuring lossy-compressed images that will have random errors that might throw off plotting results.
5. The resulting csv exported will display the ITP average value in addition to YCbCr averages (each component), Max deviation in 10bit code values, I-Error-max

Using Chroma Metric Vooya Plug-In: Paste CSV list



1. Open text file from GitHub repository resources in a text editor.
2. Paste x,y test locations list from csv text file into upper left field (red box).
3. Skip to next page

Introduction: Chroma Metric Vooya Plug-In



1. “Reset Output”: Resets conversion before selecting input format
2. “Treat Input As”: Chose SDR Gamma 2.4, HLG or PQ
3. Enable “Narrow Range” selector for broadcast video.
4. Set Min/Max Luminance in nits or cd/m²:
    1. SDR: 0 cd/m² for min, 203 cd/m² for max
    2. HLG: Defaults to 1,000nits (Normalized value established in Recommendation ITU-R BT.2408)
    3. PQ: Defaults to 10,000nits
5. “Save As”: Saves Comma-Delimited text file for import to plotting spreadsheet

Introduction: Chroma Metric Vooya Plug-In

- **T/P Color Plotting (BLUE Box) will occur if all coordinates are entered**
- **Vooya T/P plotting supports comparison of multiple movies (as seen above) by opening multiple movies, pasting csv in each and then right-clicking over T/P plot to choose desired overlay.**
- **Clicking the gear icon (upper right), allows several parameters including plotting color to be changed**
- **The plot above compares BT.2020 vs BT.709 color spaces**

Plotting Spreadsheets, Mathematics Reference

- Reference files For "Objective Color Metrics" are on Github are here:
  - Click here for reference spreadsheet templates, test pattern coordinates and other documentation.

Example: CSV Output from Vooya for ITP

Frame	Pixel Nr.	x	y	Y	Cb	Cr	I	Ct	Cp	I	T	P	Y'	u'	v'	Y-AVG	Cb-AVG	Cr-AVG	Y-Err-Max	Cb-Err-Max	Cr-Err-Max	I-Err-Max	TP-Err-Max	ΔE-ITP-AVG	ΔE-ITP-Err-Max	filterRadius	nits	min_nits	max_nits	Input
6	1	20	70	100	512	512	0.041115144347	0.000509813619	0.000221268860	0.041115144347	0.000254906810	0.000221268860	0.041096252342	0.199069492154	0.467035592801	100	512	512	0	0	0	0.000019253936	0.000555760576	0.400387197733	0.400387674570	5	0.038748	0.000	10000	YCbCr PQ-BT.2100
6	2	60	70	104	512	512	0.045681327570	0.000509834191	0.000221253573	0.045681327570	0.000254917095	0.000221253573	0.045662437069	0.198965862456	0.467143074478	104	512	512	0	0	0	0.000019227115	0.000555773382	0.400395959616	0.400396227837	5	0.0489189	0.000	10000	YCbCr PQ-BT.2100
6	3	100	70	109	512	512	0.051389062695	0.000509855194	0.000221237910	0.051389062695	0.000254927597	0.000221237910	0.051370173734	0.198861284186	0.467251523314	109	512	512	0	0	0	0.000019199681	0.000555786421	0.400404691696	0.400404900312	5	0.0638065	0.000	10000	YCbCr PQ-BT.2100
6	4	140	70	115	512	512	0.058238351294	0.000509875427	0.000221222768	0.058238351294	0.000254937714	0.000221222768	0.058219463822	0.198761843668	0.467354628506	115	512	512	0	0	0	0.000019173212	0.000555798935	0.400413483381	0.400413274765	5	0.0851638	0.000	10000	YCbCr PQ-BT.2100
6	5	180	70	120	512	512	0.063946095719	0.000509889269	0.000221212379	0.063946095719	0.000254944634	0.000221212379	0.063927209268	0.198694615677	0.467424325240	120	512	512	0	0	0	0.000019155079	0.000555807492	0.400418847799	0.400418996811	5	0.106158	0.000	10000	YCbCr PQ-BT.2100
6	6	220	70	127	512	512	0.071936942292	0.000509905286	0.000221200328	0.071936942292	0.000254952643	0.000221200328	0.071918057025	0.198617707905	0.467504048391	127	512	512	0	0	0	0.000019134073	0.000555817387	0.400425285101	0.400425583124	5	0.140959	0.000	10000	YCbCr PQ-BT.2100
6	7	260	70	134	512	512	0.079927792668	0.000509918387	0.000221190445	0.079927792668	0.000254959194	0.000221190445	0.079908908372	0.198555556223	0.467568468306	134	512	512	0	0	0	0.000019116869	0.000555825478	0.400431096554	0.400430977345	5	0.182769	0.000	10000	YCbCr PQ-BT.2100
6	8	300	70	142	512	512	0.089060196521	0.000509930742	0.000221181107	0.089060196521	0.000254965371	0.000221181107	0.089041313142	0.198497621096	0.467628512102	142	512	512	0	0	0	0.000019100631	0.000555833103	0.400436311960	0.400436073542	5	0.240205	0.000	10000	YCbCr PQ-BT.2100
6	9	340	70	149	512	512	0.097051052161	0.000509939818	0.000221174234	0.097051052161	0.000254969909	0.000221174234	0.097032169457	0.198455496542	0.467672166382	149	512	512	0	0	0	0.000019088691	0.000555838691	0.400440096855	0.400439798832	5	0.299927	0.000	10000	YCbCr PQ-BT.2100
6	10	380	70	162	512	512	0.111891216747	0.000509953536	0.000221163826	0.111891216747	0.000254976768	0.000221163826	0.111872335065	0.198392577697	0.467737364548	162	512	512	0	0	0	0.000019070629	0.000555847131	0.400445282459	0.400445431471	5	0.437825	0.000	10000	YCbCr PQ-BT.2100

Coordinate To measure

Measured value 10-bit YCbCr

Measured value Normalized as ITP value PQ-BT.2020

Measured value Normalized as L*u'v' value CIE 1976

Average, Deviation Max in YCbCr and ITP

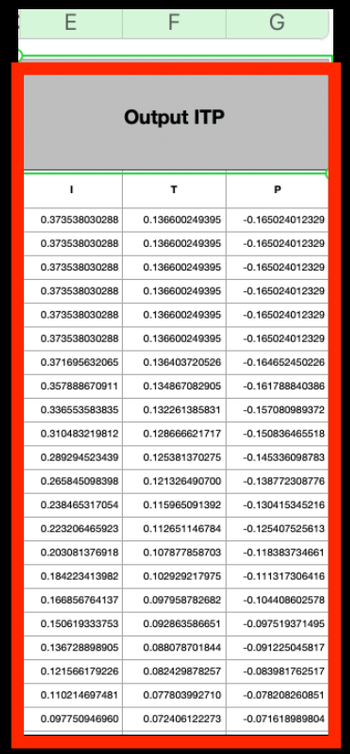
Averaging Filter Radius Value

NITs calculated from LMS

GUI Settings Video Format Min/Max Luminance

1. Above are a few rows output from a single Vooya test of the Sarnoff Yellow brick road pattern using the latest version of the Chroma Metric Plug-in.
2. To plot the sampled values, every row of ITP values must be copied into the clipboard (Command-C after highlighting the ITP columns and rows)
3. The ITP values get pasted into the spreadsheet template based on what formats you are trying to compare.
4. There are different spreadsheets for HLG vs SDR; SDR vs HLG, HLG vs PQ
5. There are different spreadsheets targeted for specific comparisons. Some examples include: HLG vs SDR; SDR vs HLG, HLG vs PQ
6. There are newer spreadsheets for plotting u'v' for absolute chromaticity

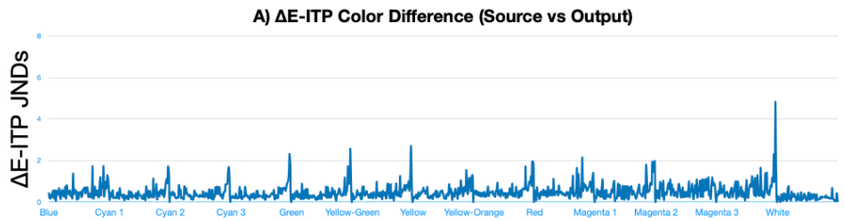
Example: Pasting results into plotting spreadsheet

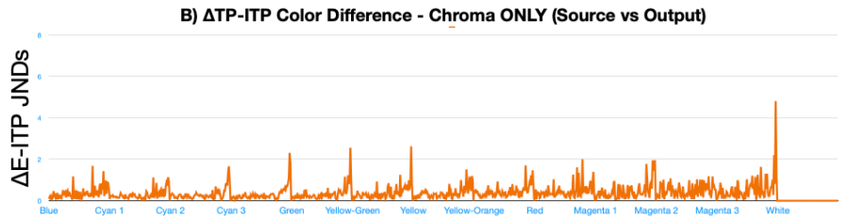


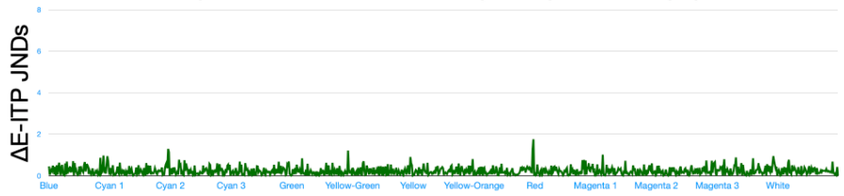
E	F	G
	Output ITP	
I	T	P
0.373538030288	0.136600249395	-0.165024012329
0.373538030288	0.136600249395	-0.165024012329
0.373538030288	0.136600249395	-0.165024012329
0.373538030288	0.136600249395	-0.165024012329
0.373538030288	0.136600249395	-0.165024012329
0.373538030288	0.136600249395	-0.165024012329
0.371695632065	0.136403720526	-0.164652450226
0.357888670911	0.134867082905	-0.161788840386
0.336553583835	0.132261385831	-0.157080989372
0.310483219812	0.128666621717	-0.150836465518
0.289294523439	0.125381370275	-0.145336098783
0.265845098398	0.121326490700	-0.138772308776
0.238465317054	0.115965091392	-0.130415345216
0.223206465923	0.112651146784	-0.125407525613
0.203081376918	0.107877858703	-0.118383734661
0.184223413982	0.102929217975	-0.111317306416
0.166856764137	0.097958782682	-0.104408602578
0.150619333753	0.092863586651	-0.097519371495
0.136728898905	0.088078701844	-0.091225045817
0.121566179226	0.082429878257	-0.083981762517
0.110214697481	0.077803992710	-0.078208260851
0.097750946960	0.072406122273	-0.071618989804

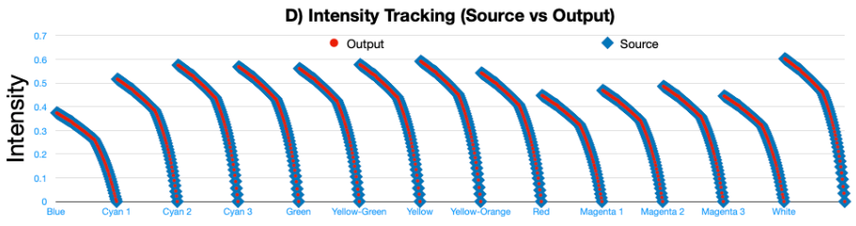
1. **ITP values previously copied into the clipboard, get pasted into the “Output ITP” columns.**
2. **The spreadsheet templates contain reference measurements for comparison to the new results pasted into them.**
3. **If you need to test other patterns, new coordinates, reference values need to be gathered and constructed into a new spreadsheet template.**

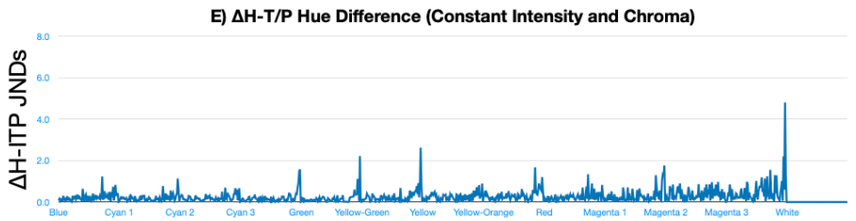
Example: Pasting results into plotting spreadsheet

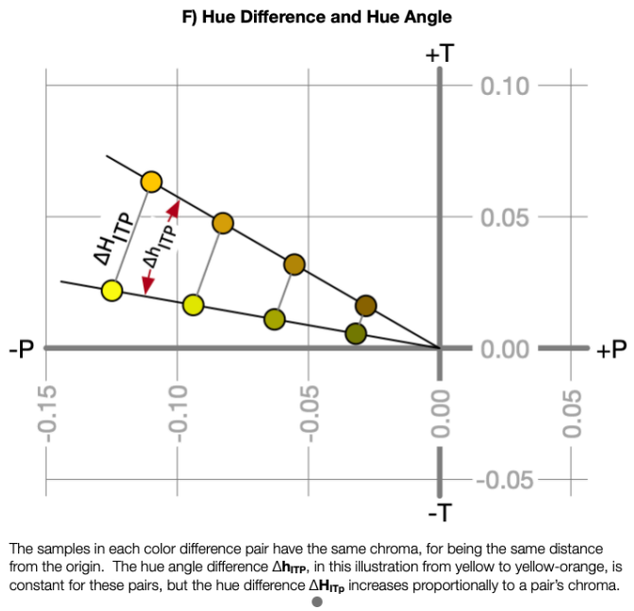




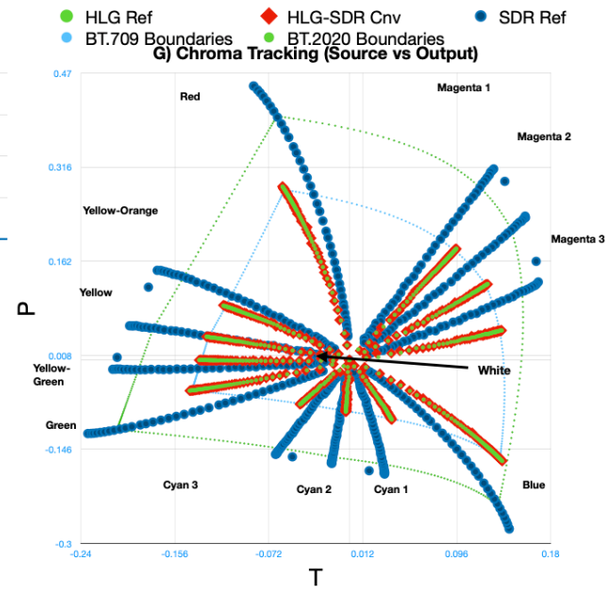


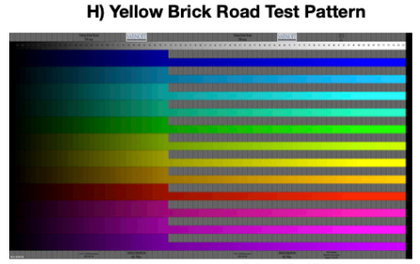






The samples in each color difference pair have the same chroma, for being the same distance from the origin. The hue angle difference Δh_{ITP}, in this illustration from yellow to yellow-orange, is constant for these pairs, but the hue difference ΔH_{ITP} increases proportionally to a pair's chroma.





1. The spreadsheet template above compares 3 different video formats without conversion in one plot (HLG vs PQ vs SDR-Passthrough in an ITP container).
2. It shows subtle error in the ΔE-ITP plot. ΔE-ITP shows a JND(Just-Noticable-Difference) for any value above 1.
3. Learning how to read these plots and interpret them takes a little experience.
4. It's important to remember that the filter radius could affect the plots results.

UHD HDR-SDR Objective Color Metrics Testing

ANNEX 1

Installing Python and Dependencies in MacOS

1. Install Python 3.10 from python.org
    - Run Python3 "Install Certificate" installer
    - Run Python3 "Update Shell Profile installer"
2. Upgrade PIP and install necessary modules from “Terminal"
    - pip3 install --upgrade pip
    - pip3 install matplotlib
    - pip3 install dumpy
3. Add the following to ~/.zprofile:

```
alias python=‘python3’

# Set explicit path to Python for Vooya
export # Vooya Python path control
export HDR_CG_PYLIB=/Library/Frameworks/Python.framework/Python

# Setting PATH to current Python version
PATH="/Library/Frameworks/Python.framework/Versions/Current/bin:${PATH}"
export PATH
```