



## Application Note #9

# How to derive and use a Color Correction Matrix to improve display measurements

### 1. Introduction

The purpose of a Color Correction Matrix (CCM) is to help improve inter-instrument agreement in emission (i.e. display and light sources) measurements. Display measurements are typically done using two instrument types: spectroradiometers and colorimeters. Spectroradiometers—such as the Eye-One Pro—measure the display light in separate wavelength bands; these bands are located at fixed intervals, usually five or ten nanometers (nm) apart, between 380 and 730 nm. Low cost colorimeters—such as the DTP94, the Spyder2, the Spyder3, and the Eye-One Display—typically have three sensors, whose sensitivity **roughly** corresponds to the Standard Observer XYZ tristimulus responses.

A spectroradiometer can be used to measure any display type, be it an older Cathode Ray Tube (CRT) display, a standard gamut LCD, or a wide-gamut LCD, without any need to correct the measured data. On the other hand, a colorimeter is generally tuned for a display type, with some instruments having a separate calibration for each type (see for instance the “Display type” selection in the Display Check tab of the PatchTool Preferences dialog).

**Important:** Not all colorimeters are inaccurate! In effect, some (very) high end instruments have sensitivities essentially matching the Standard Observer XYZ tristimulus responses and can be used to measure any display without correction. Unfortunately, the less expensive devices are only accurate for the measurement conditions they were designed for (i.e. to match specific CRT and LCD primaries); for other conditions, a Color Correction Matrix can significantly improve their accuracy.

With the advent of wide-gamut displays, many have found that their older colorimeters could not accurately evaluate their display’s performance. A CCM is then a cost-effective solution to extend the operational life of these instruments, and it can also improve inter-instrument agreement on standard gamut displays!

In practice, this means that a CCM can:

- Improve the match between measurements taken with two instruments; these instruments can be of the same model or be different models with different technologies.
- Correct the response of a colorimeter designed for standard LCD displays when doing measurements on a wide gamut display.

A CCM is typically computed from measurements made with a higher-accuracy instrument, which acts as a REFERENCE, and measurements made with a lower accuracy colorimeter, called the TARGET. High-end instruments that can be used as reference include those manufactured by Photo Research (PR-655, PR-705, PR-730, PR-521, etc.) and Minolta (CS-2000, CS-1000, CA-310, CA-210, etc.). When such instruments are not available, the best alternative is to use an Eye-One Pro.

**Note:** High-end instruments usually have built-in Color Correction Matrices support. For example, the Photo Research PR-521 brochure mentions that you can “...add up to six sets of color correction factors to maximize accuracy when measuring exotic sources”. As well, one of the main features of the Minolta CA-210 is its “Integrated matrix correction function”. This capability is now available for the instruments supported by PatchTool.

There are essentially two methods to derive a Color Correction Matrix:

- i- **Best-fit:** Measure XYZ or L\*a\*b\* for many patches with both instruments and find a matrix by best-fit. They are variants in how the fit is obtained; one can minimize the XYZ error, or minimize the L\*a\*b\* error using a given color-difference formula (with the fit varying according to the selected formula).
- ii- **Four-Color:** Measure XYZ or xyY for four patches (red, green, blue, and white) and find a matrix with the method presented in [ASTM E1455-2010](#) (*Standard Practice for Obtaining Colorimetric Data from a Visual Display Unit Using Tristimulus Colorimeters*). This is the method used in [PatchTool](#).

The best-fit method may provide somewhat smoother results over a display gamut if the fit is based on several “random” colors. On the other hand, the ASTM Four-Color method guarantees that the primaries will be “exactly” matched, and the method is more convenient to perform when data is gathered one patch at the time. Our tests have shown that the corrected values are essentially the same with both methods (i.e. the differences in the corrected values are non-noticeable on average). Finally, it is worth noting that former versions of the ASTM method were based on best-fit, now replaced by the Four-Color method.

#### **Additional notes:**

- i- A matrix is always assigned to a specific combination of **display + target instrument**. In particular, if your display has settings which affect its primaries, you should first select these settings, do a display profile, and then use the calibrated display to perform the REFERENCE and TARGET measurements.
- ii- A Correction Matrix improves the inter-instrument agreement between a REFERENCE instrument and a TARGET instrument. While this procedure may improve the absolute accuracy of the TARGET instrument, if the REFERENCE is more accurate, it cannot improve the absolute accuracy of the REFERENCE instrument.
- iii- While the TARGET is often a lower accuracy device, it need not be. A Correction Matrix would still improve the inter-instrument agreement between the REFERENCE and the TARGET.
- iv- The PatchTool Correction Matrix tool can be used to determine matrices for any instrument and the exported correction matrices may be used with any XYZ data measured with this instrument. Of course, only the matrices derived for instruments supported by PatchTool can be used in PatchTool Display Check.
- v- The PatchTool Correction Matrix tool can be used to derive matrices for either 2 degree or 10 degree Observer data. However, please note that only matrices computed from 2 degree Observer data can be used in PatchTool Display Check.

In the following pages, we see how to compute a Correction Matrix and how the TARGET instrument measurements match those of the REFERENCE instrument when they are processed with a Correction Matrix.

## 2. Computing the Color Correction Matrix

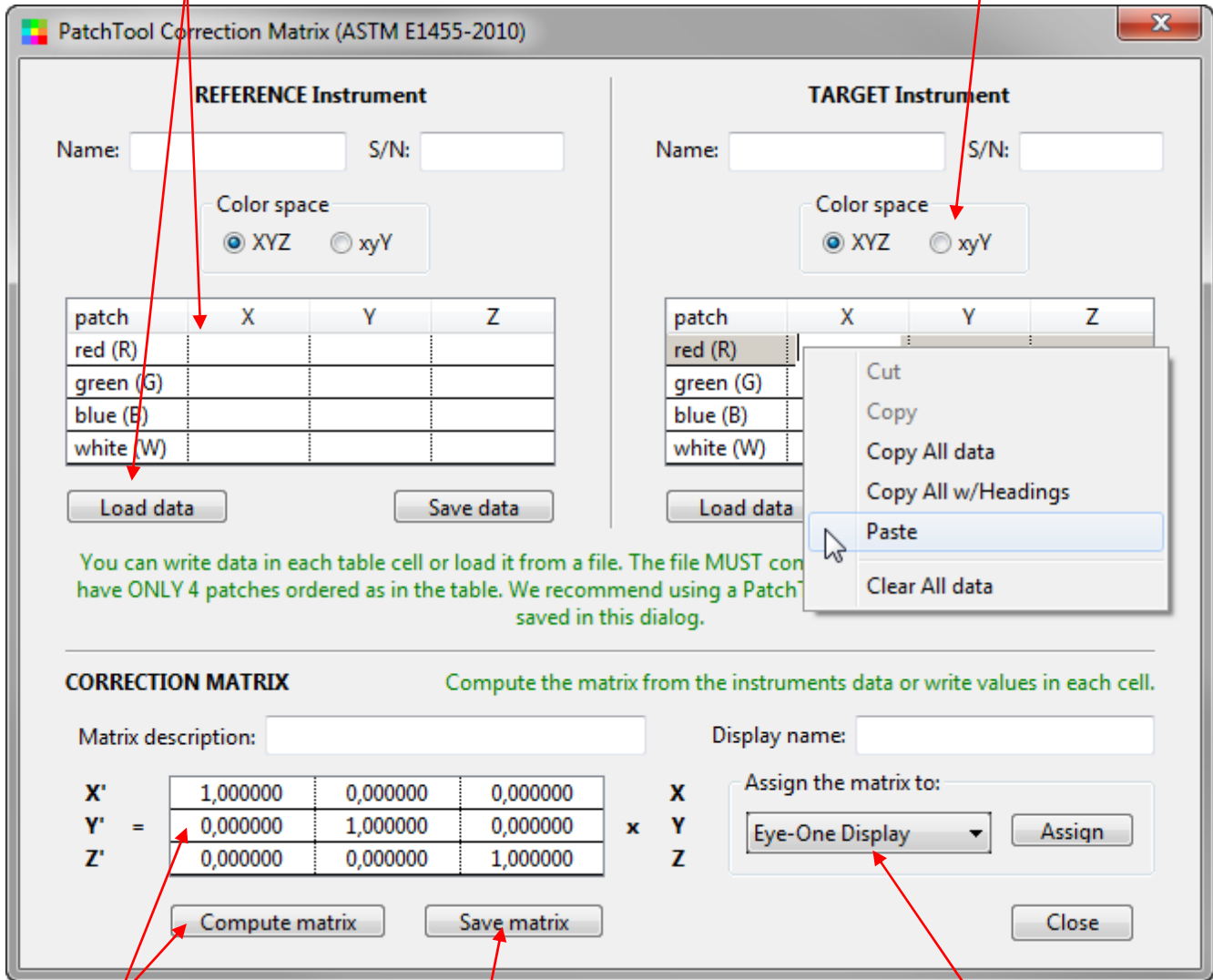
The screenshots in this tutorial were all taken from [PatchTool](#). The measurements required to derive the Color Correction Matrix (CCM) are done with the **Display Check tool**; the matrix is derived using the **Correction Matrix tool**; the test data used to demonstrate how to use the CCM is generated with the **Gamut Tools List generator tool**; and the test data measurements are done, once again, with Display Check.

The Correction Matrix tool dialog is shown below. Since it is based on ASTM E1455, i.e. the Four-Color method, the REFERENCE and TARGET data tables only need to represent red, green, blue, and white samples. Data from any instrument can be either manually entered, loaded from a simple text file (see an example on the next page), or copied from a spreadsheet using Copy/Paste. If the instruments are supported by PatchTool, the REFERENCE and TARGET measurements can be obtained with PatchTool Display Check, as shown in Section 2.2.

The “PatchTool Correction Matrix” dialog is opened by selecting the “Tools/Correction Matrix” menu.

Data entry options: manual entry; paste cells from a spreadsheet, or load from a file.

Enter data as XYZ or xyY coordinates.



You can enter data manually, paste cells from a spreadsheet, or compute a matrix from REFERENCE and TARGET data.

Save as a file that can be opened in the “[Color Correction Matrix](#)” dialog that can be accessed from the Display Check tool.

Directly assign a matrix to a colorimeter supported by PatchTool [Display Check](#).

## 2.1 Measuring the REFERENCE and TARGET data in PatchTool

As in any display measurements, and particularly in this case where we characterize a display with only four colors, it is important to be aware of the factors which can affect the results; please consult the guidelines presented in [Appendix A](#).

Here is a procedure in how to use **PatchTool Display Check** to obtain Correction Matrix measurements:

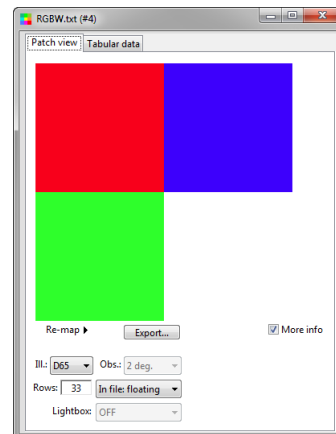
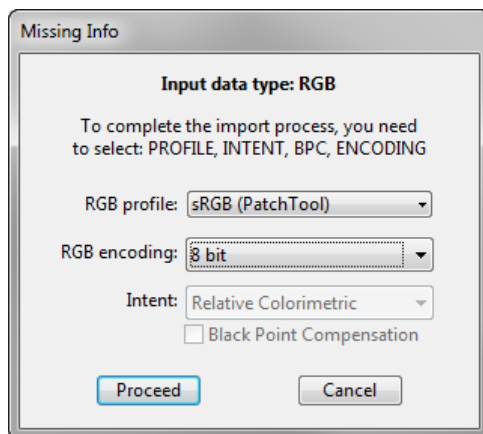
- i- Open the “RGBW.txt” file provided with PatchTool; the file content is shown below. The file is located within the PatchTool application folder::

“... \PatchTool\correction-matrices\RGBW.txt”

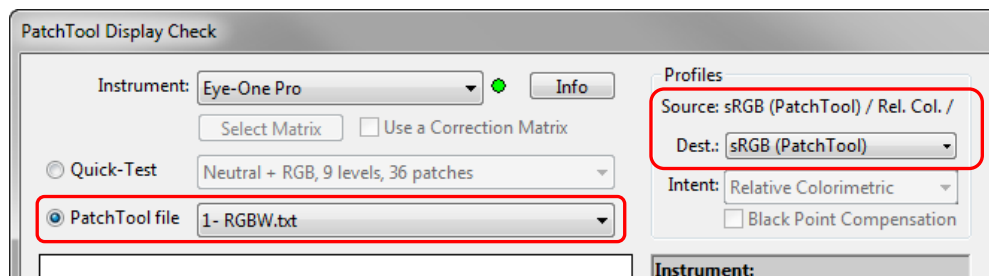
R	G	B
255	0	0
0	255	0
0	0	255
255	255	255

The content of the “RGBW.txt” file provided with PatchTool for Correction Matrix measurements.

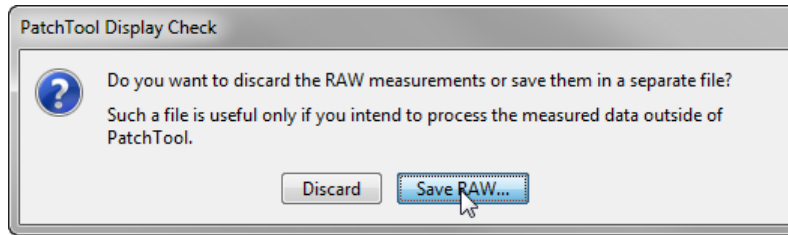
- ii- Assign the “sRGB (PatchTool)” profile and 8 bit encoding to the file. The selected profile is irrelevant as long as the SAME profile is selected as the Destination profile in Display Check. The opened PatchTool file is shown below-right.



- iii- Open Display Check. Select your REFERENCE instrument; we recommend using the Eye-One Pro. Please note that, by default, this instrument does not use a Correction Matrix, which explains why the matrix controls are disabled, as shown in the screenshot below.
- iv- Select the “PatchTool file” radio button; select the “RGBW.txt” file. Select “sRGB (PatchTool)” as the Destination. By selecting the same profile for the Source and Destination, the RGB values are sent directly at the display.

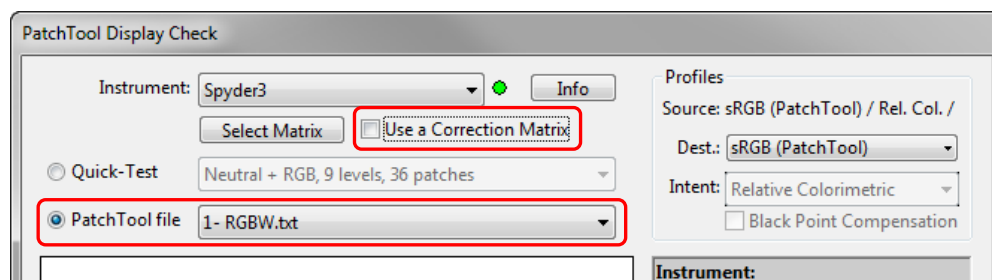


- v- Press the “Start” button and follow the instructions. When the measurements are completed, **save the RAW file**. A Compare file will open; there is no need to save it.



**Important:** Because it contains Emission data, this RAW file cannot be opened as a standard PatchTool file. It can only be loaded as measurement data in the Correction Matrix tool.

- vi- Re-open Display Check. Select one of the colorimeters (DTP94, Spyder2, Spyder3, or Eye-One Display) as your TARGET instrument. **Uncheck** “Use a Correction Matrix” since the purpose of this measurement is to derive a correction matrix for the instrument.



- vii- Select the “PatchTool file” radio button; once again select the “RGBW.txt” file and select “sRGB (PatchTool)” as the Destination (shown just above).
- viii- Press the “Start” button and follow the instructions. When the measurements are completed, **save the RAW file**. A Compare file will open; there is no need to save it. We now have all the data required to compute the correction matrix.

## 2.2 Entering the data and computing a Color Correction Matrix

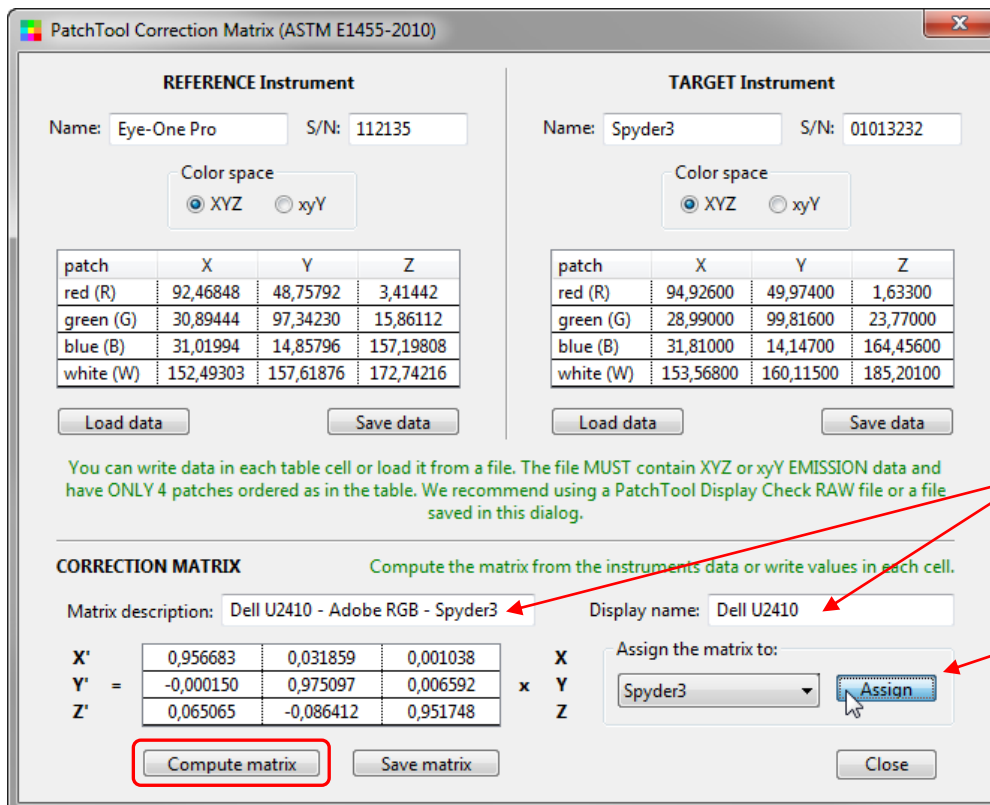
You can write data in each table cell or load it from a file. The file MUST contain XYZ or xyY EMISSION data, and have ONLY 4 patches ordered as in the table. We recommend loading a **PatchTool RAW** file obtained with Display Check (measured from the “RGBW.txt” color list as shown in Section 2.1), or a file previously saved from the Correction Matrix dialog.

You can also import a plain text file; here is an example of a text file that can be imported as REFERENCE or TARGET measurements. The example shows xyY data (CIE 1931 Chromaticity) but XYZ data could be used as well. The color space variables and the data values are separated by a single Tab; the decimal separator in the example is a comma but a period works as well (the separator must be the same for all values in the file).

x	y	Y	
0,640849	0,33643	49,804806	
0,215388	0,675726	98,792537	
0,152704	0,074807	14,903675	
0,319823	0,33064	160,280967	

It is important to order the data so that it represents, from TOP to BOTTOM, **Red**, **Green**, **Blue**, and **White** measurements.

If you have compatible measurements files, just load the REFERENCE and TARGET files in their respective tables using the “Load data” buttons. The screenshot below shows the dialog with an **Eye-One Pro** used as a **REFERENCE** and a **Spyder3** used as a **TARGET**. The measurements were done on a Dell U2410 wide gamut display set to Adobe RGB.



Complete these fields; they will be included in the saved file.

Assign the matrix to one of the PatchTool supported instruments.

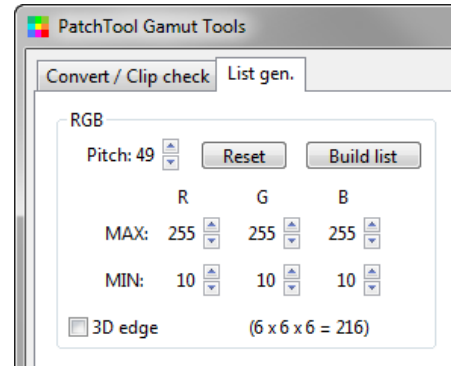
Once the REFERENCE and TARGET tables are full, you can generate a matrix by pressing the “Compute matrix” button. Of course, if you already have matrix data, you can enter it directly in the CORRECTION MATRIX table. You can save the matrix in a file (the file has a “.ccmx” extension); this file can be opened from the PatchTool Display Check tool and from other applications which support the file format. You can also directly assign a matrix to the instruments supported by PatchTool Display Check without saving it in a file.

### 3. Using a Color Correction Matrix

In this section we compare measurements done with two instruments, an Eye-One Pro and a Spyder3, on a wide gamut display. The display is a Dell U2410 set and profiled in the Adobe RGB space. The display profile was done quite a long time ago and, while quite good, is not optimal; however, this is not a problem for the purpose of this demonstration since we want to see how the two instruments match.

The Correction Matrix was measured and computed as shown in the preceding section; the matrix measurement data and the resulting matrix is shown in the screenshot on the bottom of the preceding page. In order to show the effect of this matrix, we now present a comparison of the measurements with and without the correction applied to the Spyder3 data.

To compare the instruments, we need more than four patches. Ideally we would like patches covering the entire display gamut but not too many patches so that the measurement time is not too long. We can easily generate an RGB list with PatchTool Gamut Tools' List generator. With the settings shown on the right, we create a color list that encompasses most of the gamut, with a uniform distribution that comprises gamut edge colors (file name proposed by the program: *RGB-list\_49-pitch\_216-patches.txt*). The RGB coordinates start at (10, 10, 10) and end at (255, 255, 255) with a pitch of 49; they are located on a (6 x 6 x 6) 3D grid, for a total of 216 patches.

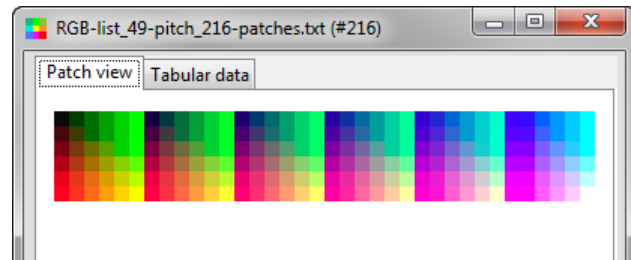
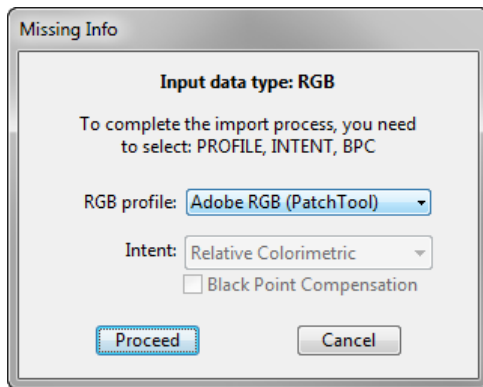


#### 3.1 Inter-instrument agreement WITHOUT a Correction Matrix

We first measure the color list with both instruments, the Eye-One Pro and the Spyder3, with **NO correction matrix** selected for the Spyder3.

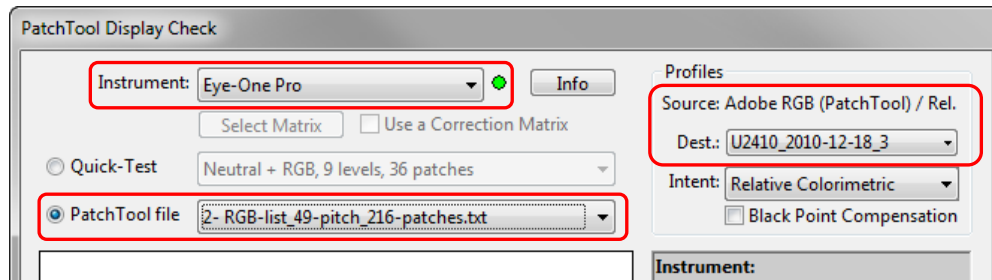
Here is the procedure:

- i- Open the RGB color list we generated to test the instruments. Assign the “Adobe (PatchTool) profile to the file; we use Adobe RGB in this example because our wide gamut display is set to match this color space. If we had tested a standard gamut display, we would have likely selected the sRGB space. In both cases we could also have selected the display profile as the RGB space.

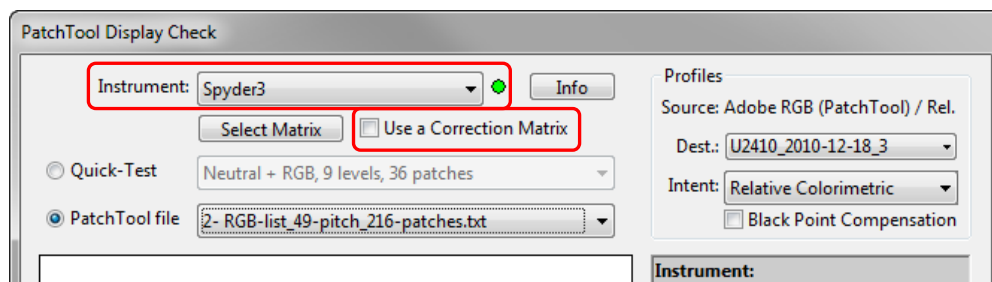


- ii- Open Display Check. Select the REFERENCE instrument, the **Eye-One Pro** in this example. Please note that, by default, the Eye-One Pro does not use a Correction Matrix, which explains why the matrix controls are disabled, as shown in the screenshot on the next page.

- iii- Select the “PatchTool file” radio button; select the “RGB-list\_49-pitch\_216-patches.txt” file. You will notice that the “Source” is “Adobe RGB (PatchTool)”, as assigned when we opened the file. Select **your display profile** (named “U2410\_2010-12-18\_3” in the screenshot) as the Destination. Note: In a two-display system, *your display profile* may not be the same as the *default* profile which is associated to the principal display.



- iv- Press the “Start” button and follow the instructions. You may discard the RAW measurements file when asked if you want to save it since **the analysis is based on the Compare file**. A Compare file will open; you should save it for future reference and leave it open.
- v- Re-open Display Check. Select the TARGET instrument, which is **Spyder3** in our example. **Uncheck** “Use a Correction Matrix” since the purpose of this measurement is to get the data without a correction matrix. Select the “PatchTool file” radio button; once again select the “RGB-list\_49-pitch\_216-patches.txt” file and check that the Destination is still your **display profile**.

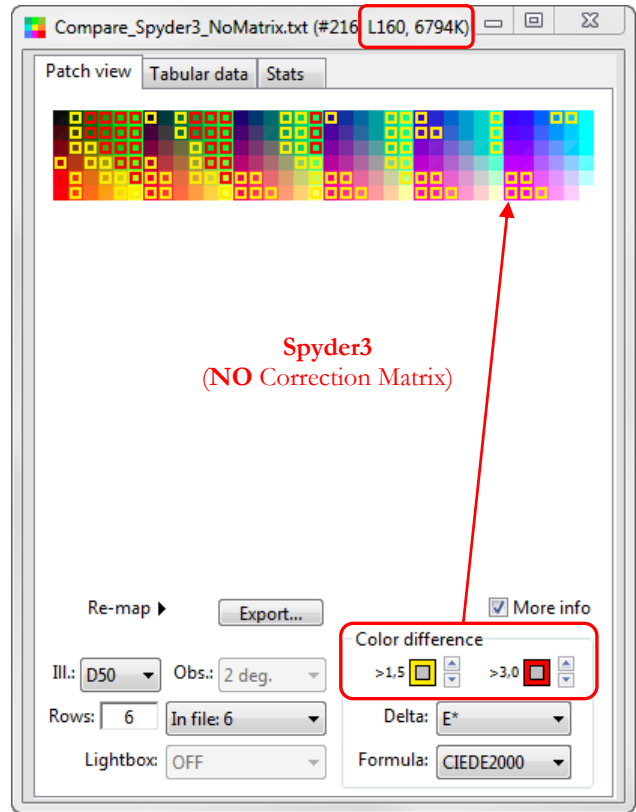
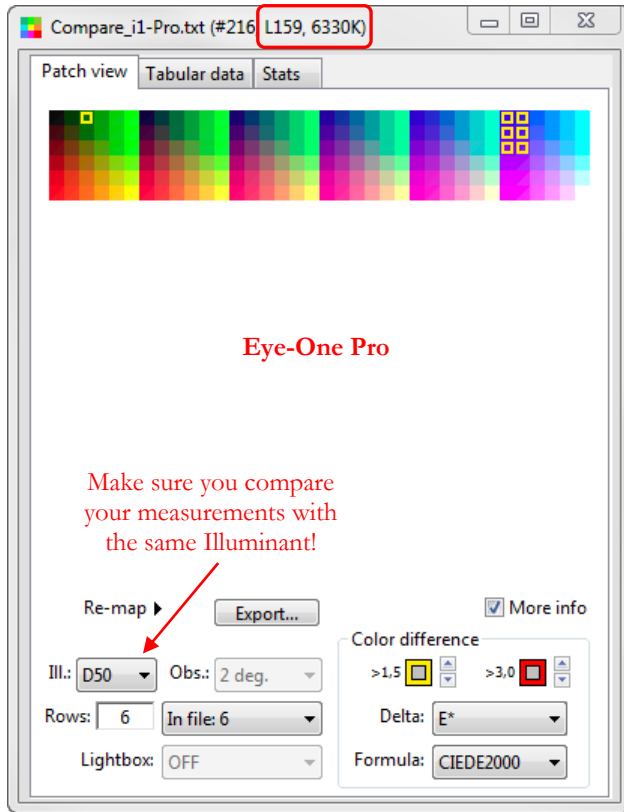


- vi- Press the “Start” button and follow the instructions. Again, you may discard the RAW measurements file when asked if you want to save it. A Compare file will open; you should save it for future reference and leave it open. We will now analyze our measurements.

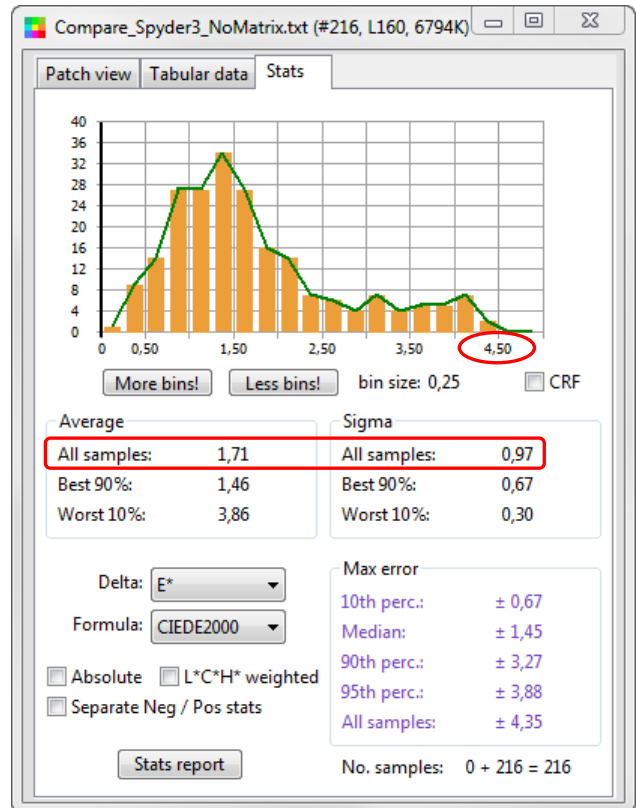
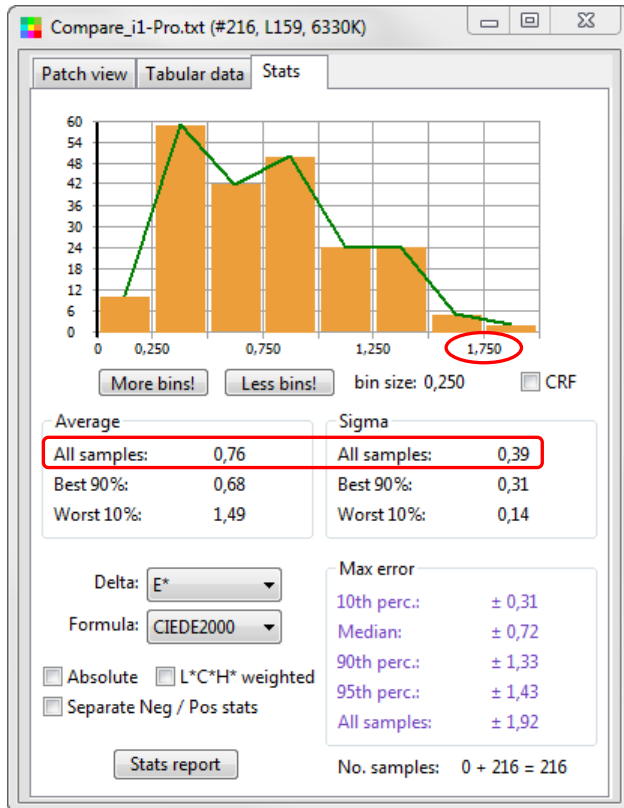
The Compare files for the Eye-One Pro and Spyder3 (with **NO** Correction Matrix) are shown on the next page.

**Note:** If you are performing similar measurements as you read this tutorial, you should leave PatchTool opened since we will perform other measurements.

# Eye-One Pro vs Spyder3 (NO Correction Matrix)



The first thing we notice is that the Spyder3 window has many patches with errors over 1.5 DeltaE\* (CIEDE2000) while there are only 7 patches with such errors for the Eye-One Pro. This is expected since the Eye-One Pro was used to profile the display. The Luminance match is excellent, 159 cd/m<sup>2</sup> for the Eye-One Pro and 160 cd/m<sup>2</sup> for the Spyder3. There is however a good difference in the measured CCT, with 6330 K for the Eye-One Pro and 6794 K for the Spyder3. The screenshots below show the corresponding stats, which are quite different.

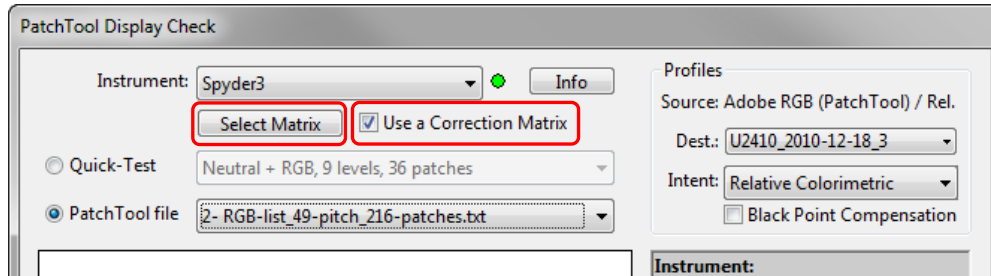


### 3.2 Inter-instrument agreement WITH a Correction Matrix

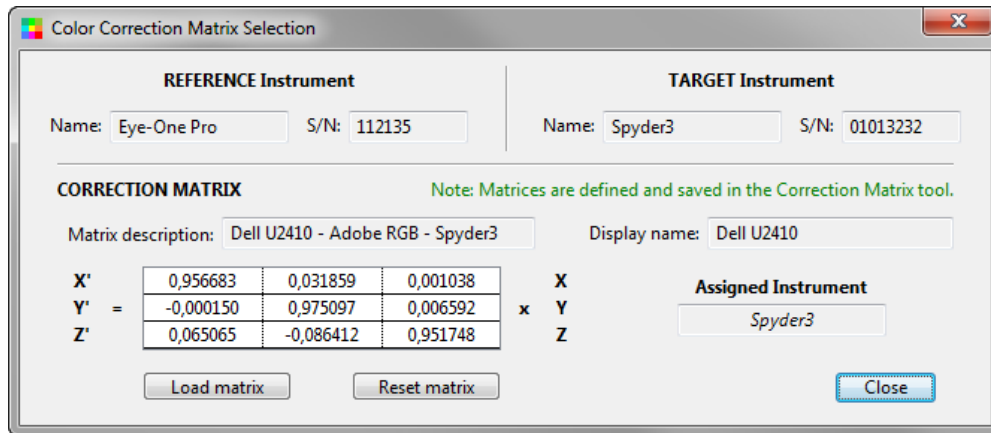
We already measured the color list with the REFERENCE, the Eye-One Pro, so there is no need to repeat it. We now perform the measurements with the **TARGET**, the Spyder3, but this time **we apply a correction matrix**.

Here is the procedure:

- i- Open Display Check. Select the **TARGET** instrument, which is **Spyder3** in our example. **Check** “Use a Correction Matrix” since the purpose of this measurement is to get the data with a correction matrix. Select the “PatchTool file” radio button; select the “RGB-list\_49-pitch\_216-patches.txt” file and check that the Destination is still your **display profile**.



- ii- Click on the “Select Matrix” button to open the matrix selection dialog. Make sure that the proper matrix data is loaded. In our example, the data corresponds to the matrix obtained in Section 2.1. You can load a matrix from a file (with a “.ccmx” extension) if needed. Close the dialog to return to the Display Check window.



**Note:** A selection of Color Correction Matrices files is available in the PatchTool application folder:

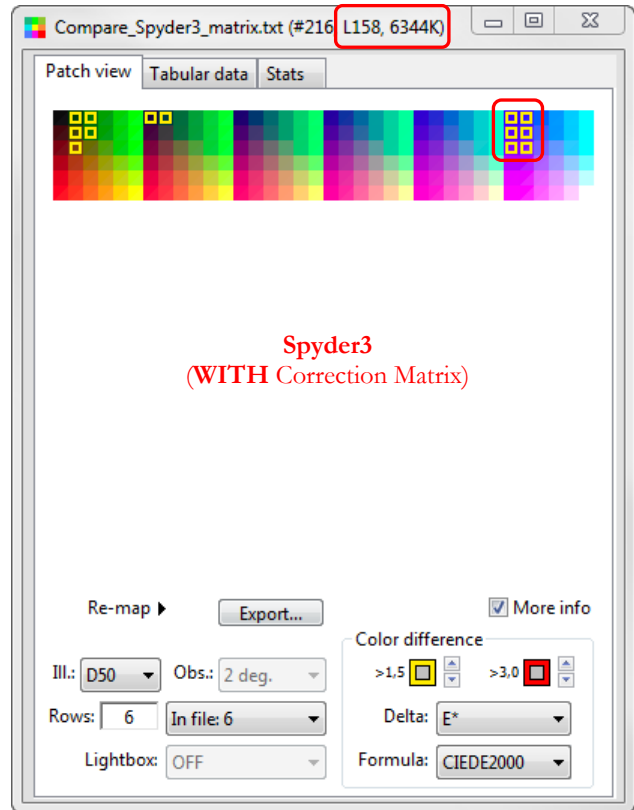
“... \PatchTool\correction-matrices\”

Please note that the data in these files was gathered from multiple sources and we cannot guarantee its accuracy. We recommend that you derive a Correction Matrix for your own setup whenever feasible

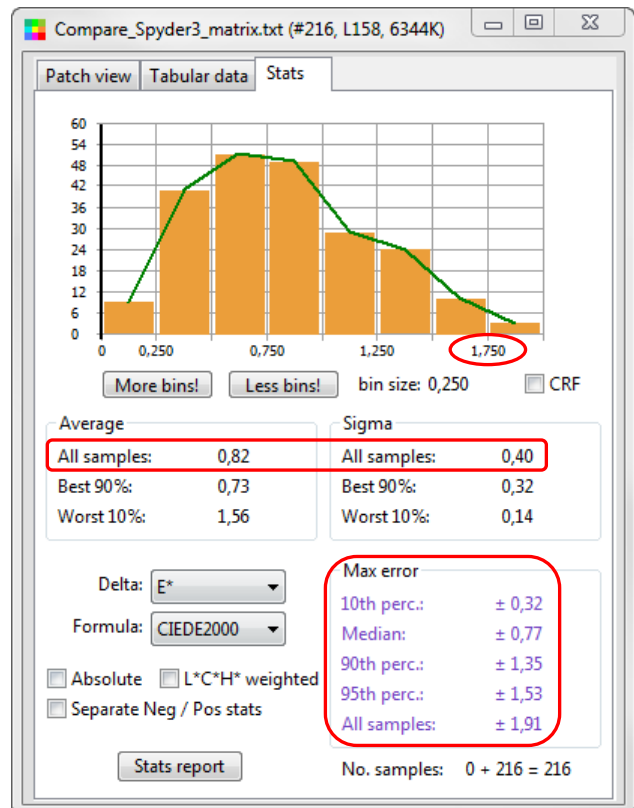
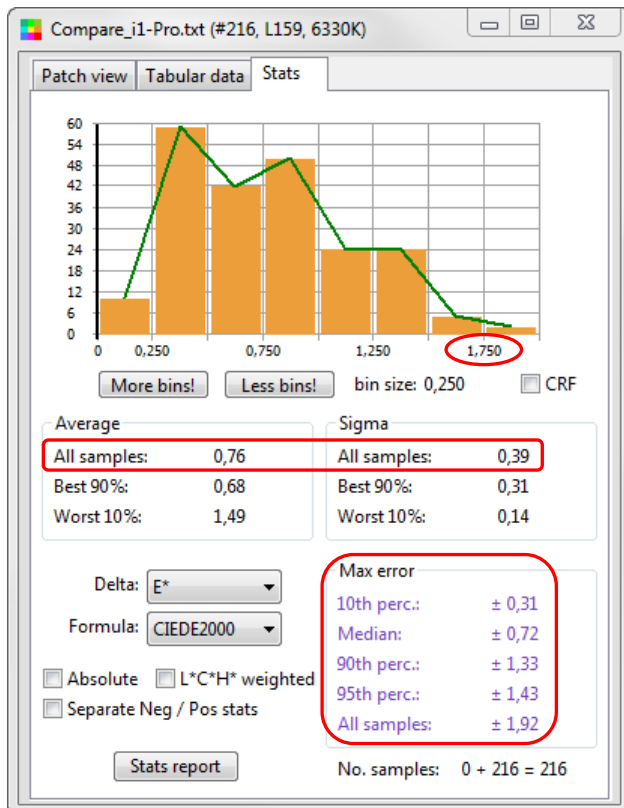
- iii- Press the “Start” button and follow the instructions. You may discard the RAW measurements file when asked if you want to save it. A Compare file will open; you should save it for future reference and leave it open. We will now compare our corrected Spyder3 measurements with the ones obtained with the Eye-One Pro.

The Compare files for the Eye-One Pro and Spyder3 (**WITH** Correction Matrix) are shown on the next page.

## Eye-One Pro vs Spyder3 (WITH Correction Matrix)



The agreement between the two instruments is now excellent, with larger color differences computed for the same patches (see for instance the six highlighted patches above). The Luminance and CCT are all quite close. The statistics of the Spyder3 measurements are almost the same as those of the Eye-One Pro. The *Average*, *Sigma*, and *Max. errors* values nearly match; even the shapes of the histograms look alike.



## Conclusion

We have shown how a Color Correction Matrix between two instruments can be derived with the Four-Color method, a fast, efficient, and deterministic method described in the ASTM E1455 standard.

We have seen that a Correction Matrix can improve the inter-instrument agreement for a specific display configuration. In our example, not only have we improved the match between the instruments, but we did it for a wide gamut display for which the colorimeter, the Spyder3, was not specifically optimized for.

## Appendix A - Factors which can affect display measurements

As with any technical measurement, there is a list of things you should be aware of in order to obtain the best assessment of the display performance. The following points should be used as a checklist before doing the measurements, or when analyzing the results.

### **Instruments and displays are not created equal**

The various instruments available for color measurements on displays are essentially of two types: colorimeters or spectroradiometers. There are pros and cons for each type of instrument. Some will prefer the colorimeter because of the perceived (and sometimes real) increased stability of the measured data. However, colorimeters can be more susceptible to changes in monitor design features such as the specific characteristics of the display primaries. A colorimeter which worked well with CRTs will not necessarily be accurate with LCD displays. Various brands and models of LCDs also use very different filters and/ or light sources which can easily affect a colorimeter's calibration; this is a problem with wide gamut LCD monitors which use a green filter quite different than the ones used in smaller gamut monitors.

When you couple the different instrument optical layouts with the numerous display types, you are bound to witness quite diverse results. For example, instruments with different Field-Of-Views (FOV) will provide different values when measuring LCD monitors with dissimilar and non-isotropic angular spread. You could well obtain matching results between instruments for some displays and non-matching results for others. For instance, on some displays, we have measured blacker black levels with a spectroradiometer than with a colorimeter.

### **Specifications do not give the complete story**

Most instruments are specified in term of inter-instrument accuracy relative to a master instrument located at the manufacturer's plant. This inter-instrument accuracy also does not even apply between different models of the same manufacturer. So we are far from being able to compare instruments based on absolute specifications; in particular, you will have a (very) hard time finding absolute chromaticity accuracy for emission measurements.

### **Your display is NOT uniform across its surface**

If you calibrate your display by placing the instrument at a certain position and in a given orientation, use the same position and orientation to make a display check (see also *Measurements on LCD displays with an Eye-One* at the [end](#) of this section). A display white point and its brightness do vary across its surface. There are sections of standards ISO 12646 and ISO 3664 dedicated to these non-uniformities (available from their Web site: <http://www.iso.org>):

ISO 12646: "Graphic technology -- Displays for colour proofing -- Characteristics and viewing conditions"

ISO 3664: "Viewing conditions - Graphic Technology and Photography"

According to ISO 12646, it is acceptable to have up to 10% brightness non-uniformity within a centered rectangular zone which covers 25% of the display area. Higher end monitors will exhibit a better uniformity than this, but the difference can still be significant (remember that we are often looking at color differences of one or two Delta-E here).

### **Your display needs to be stable before making measurements**

Whether it is a CRT or a LCD, open your monitor for at least one hour before doing critical measurements (and calibration of course!). Make sure any screen saver is disabled before leaving your system unattended. If a variation in white level is detected while doing a measurement, you will be prompted by PatchTool, and have the choice to continue or discard the measurements.

### **Your colorimeter/spectrophotometer needs to be temperature-stabilized before making measurements**

All optical sensors are subject to electronic noise. This noise varies with the instrument's temperature, usually increasing as the temperature goes up. When calibrating, you are, in effect, indicating to the instrument's firmware to subtract the present noise from all future measurements. To minimize any increase in noise, you should thus let your instrument stabilize by placing it anywhere on your display while your display stabilizes. This procedure was found to be effective by IDEAlliance while they were developing their monitor proofing certification process.

### **A display profile is matched to its hardware settings**

When you make a display profile, you are asked to set a White Point and brightness level. This adjustment is made automatically on high end systems but remains a manual task for many users. In any case, these hardware adjustments are linked to the resulting profile as well as to the graphic card Look-Up-Table (LUT), and sometimes also to the display LUTs if so equipped. See the next point for additional information on LUTs.

This means that if you select a different profile to check, you should make sure that the hardware settings correspond to this other profile. Since these settings are often manually adjusted and not recorded, there is little chance of getting the system back to the correct setting. On the plus side, we often make many profiles with the same White Point and brightness values, changing only software settings between each profile.

### **A display profile is matched to a computer's graphics card Look-Up-Tables (LUT)**

Profile calibration software use the graphics card built-in LUTs as a mean to provide neutral grays and to adjust the gamma response. Higher end monitors also have LUTs built into the monitors itself; these LUTs work in tandem with the graphics card LUTs to provide smoother tones over a large dynamic range. However, monitor LUTs are not common, and require profiling applications made specifically for such displays.

The monitor calibration (i.e. White Point and LUTs) is the first step of all display calibration procedures; because it is hardware based, it will also benefit non-color-managed applications. The display profile is then built on top of the calibrated monitor; it is thus linked to a given LUT set, and needs to be changed whenever a different profile is selected. In Windows, while the default display profile is loaded at start-up, the LUTs are not. A third party application is required, and this program is usually automatically launched at start-up; *Logo Calibration Loader* (GretagMacbeth), *ColorVisionStartup* (Datacolor) and *basICColor display4 VideoLUT Loader* (Color Solutions) are such applications. Because loading the LUTs require a dedicated third-party application, changing a Windows profile on the fly, using the display properties for instance, will not update the LUTs. For Windows XP users, there is a simple solution in the form of a small control panel, named *Color*, which can correctly assign a profile and load the corresponding LUTs without rebooting; this add-on has to be downloaded separately from the Microsoft Web site: [Color Control Panel Applet for Windows XP](#). On a Mac, changing a display profile automatically changes the LUTs. However, for all platforms, you will need a dedicated application to load monitor LUTs.

### **Measurements are not the same unless the data processing is the same**

Many profiling applications incorporate a quick profile verification procedure. The verification measurements can be presented as a graph, a data table with an average error, or a before/after image. You should be aware that when you see RGB input data, they usually mean RGB in the monitor space. Their measurements may be in D50, if presented in  $L^*a^*b^*$ , but may also be RAW emission chromaticities, relative to the actual display White, which cannot be directly compared to reference data based on standard Illuminants (a Chromatic Adaptation Transform (CAT) is required for such a comparison). These validation procedures are not well documented and can only be understood by a detailed analysis. In such conditions, it becomes hazardous to compare measurements made with different programs. This is why you will find a complete description of PatchTool's data processing in Appendix B of the [PatchTool Help](#) manual; at least you will know where PatchTool's measurements come from.

### **ICC profiles and Color Management Modules (CMM) are not created equal**

The content of an ICC profile varies depending on the application which generated it. You may be offered many options on what you want inside your profile. You can often select between a matrix profile and one based on LUTs, which can significantly increase a profile size, but can also offer better precision. There are also many decisions made by the program's creators, for which you have no control. For instance, a profile creator may add some additional profile features (tags or other content) that can only be used by its other products. What will the default rendering intent be? How many different intent tables will be embedded?

To make things even more difficult to control, a given profile may or may not be handled in the same way for some intents and BPC settings by different CMM (also called color engines, such as Adobe ACE, Apple ColorSync, Microsoft ICM, lcms, and Argyl). For example, how will Black Point Compensation (BPC) be handled for the different intents?

### Control the display environment

A strong overhead light or a nearby desk lamp will likely leak light into your darker shades measurements. In any case, whenever possible, you should work in a dimly lit environment in order to fully appreciate your display output and minimize errors due to external light contamination. Also try to maintain a uniform room temperature, which can affect the display's response.

### Measurements on LCD displays with an Eye-One Pro

While making emission measurements with an Eye-One Pro on an LCD display, it was noticed that different Luminance and Correlated Color Temperature (CCT) values were obtained, depending on the instrument's position on the display. Luminance variations by as much as 10% were measured for the same display area when rotating the spectroradiometer by 90 degrees. This problem affects Eye-One Pros with manufacturing revisions A, B, and C (shown as REV A, REV B, REV C on the instruments). According to our own measurements on a REV D unit, this problem has essentially disappeared; this has been confirmed by other owners of REV D Eye-One Pros.

The problem with earlier units is related to the polarization of the light emitted from the display. In an LCD display, the intensity of each pixel is controlled by rotating the light's polarization state between crossed polarizers, and the light coming out is linearly polarized (often at a 45 degrees angle). To check this, look at your display using a photographic polarizing filter (or polarizing sunglasses), and rotate it slowly; you should see maximum and minimum transmission for angular positions separated by 90 degrees. The display light is not seen differently by the human eye whether it is polarized or not, since we only perceive the light intensity; however, polarization can affect an instrument reading.

In order to obtain reproducible and valid measurements, we recommend making all measurements with the instrument placed at the same angle that was used for calibration. If calibration is done with the instrument suspended in its cradle, as shown in the illustrations below, all subsequent measurements should be done with the Eye-One placed vertically. It is acceptable to make measurements with the instrument turned 180 degrees from its calibration position, so that it is still vertical, as shown in the illustration on the left. Accordingly, in such a case, measurements should not be done with the instrument positioned horizontally, or at an angle, as shown in the illustration on the right.



**Note:** "Older" CRT displays do not emit polarized light and are thus not susceptible to errors due to instrument orientation. As for the Eye-One Display and the Spyder2 colorimeters, their simpler optical layout makes them immune to this effect.

After what you read in the previous pages, we are sure you will feel gratified when a display check shows a low average error, since you know that such an outcome is conditional to the understanding and control of many parameters, and that not much is required to push the results out of an acceptable zone.

### **The BabelColor Company**

Founded in 2003, *The BabelColor Company* is dedicated to the development and sale of specialized color translation software and color tools. It also provides color consulting services for the professional and industrial markets.

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