

SCANNERS – HOW TO ENSURE ACCURATE COLOR RENDERING AND MEASUREMENTS OF PRINTED TEST TARGETS FROM COLOR PRINTERS

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Abstract: With evolving and rapidly changing technology of digital cameras, printers, and monitors, one would expect that use of scanners would diminish over the time. Although digital cameras are the most popular devices used to capture photos, scanners are still widely used for converting media such as pictures, artwork, documents, transparencies, slides, and film negatives into an electronic format.

This article discusses calibration, characterization, and profiling of lower-end scanners. Use of ISO scanner calibration targets, handful of software applications, and "how-to's" is described. Comparisons are made for different scanner targets and software applications.

Keywords: Color Printer, Printing, Calibration

1. MEASURING SCANNER DYNAMIC RANGE AND THE D_{max} VALUES

ISO 21550:2004 standard specifies methods for measuring and reporting the dynamic range of scanners. There are three common methods to determine the maximum density D_{max} :

1. The darkest patch which shows a difference in the averaged digital value (RGB) of at least 1 compared to the previous lighter patch -Method 1;

2. The darkest patch which shows a visual difference in comparison to the next lighter one by using a gamma correction - Method 2;

3. The darkest patch showing a signal to noise ratio (S/N) larger than a given value, e.g. 1 - Method 3.

Method 3 is based on S/N ratio is the most objective method for determination of D_{max} values of a scanner. The engineering definition of dynamic range is: D_{max} corresponds to the maximum recordable signal (the raw value at which the sensor saturates, D_{min}) divided by the read noise, which is the lowest recordable signal (D_{max}) [3].

2. D_{max} ESTIMATION FOR MICROTEK 5800 SCANNER

1. Use the Kodak Q13 Gray Scale step chart. This gray scale target is calibrated for density increment of 0.1 over 20 steps. Maximum density is 2.0D.

2. Scan the step wedge with color management turned off as 48-bit positive color image.

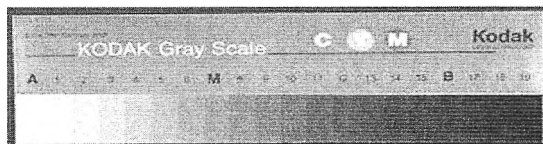


fig.1: Kodak Q13 Gray Scale step chart

Table 2. Danes-picta BST13 (Kodak Q13) data on this step wedge

Part Number	Steps	Density increment	F-stop equiv.	Dmax	Size
BST13	20	0.1	1/3	2.0	1" x 9 1/5"

3. The figure bellow shows the correct scanner wizard setup. Remember to scan with no embedded profiles and no other corrections than the gamma curve, which has to be set to 1. Now you are describing the scanner's dynamic range, so the gamma needs to be 1, meaning what comes in scanned, has to come out on the monitor unchanged – theoretically:

Estimation of D_{max} – as in method 3 [1]:

1. Open Imatest Software and launch the Step-chart module;

2. Select and open the scanned Kodak Q13 image file (tif);

3. Select the area of step wedges by clicking and dragging, excluding the numbers;

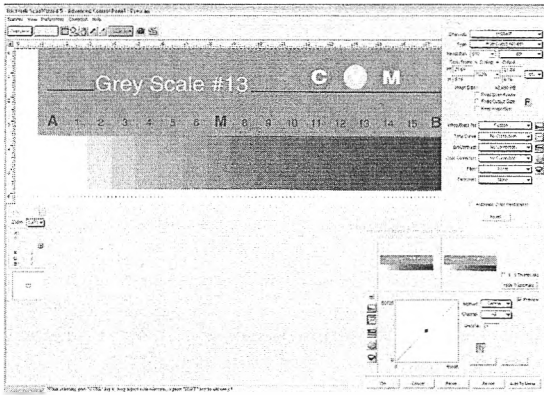


fig.2: Kodak Q13 Scan Target for Dmax Research with gamma 1 and no profile embedded

4. Adjust the selected area by aligning the cyan rectangles with step numbers. Click Zoom in to reveal the numbers. Click Yes, Continue:



fig.3: Kodak Q13 Scan Target for Dmax Research with gamma 1 and no profile embedded

5. Data is calculated and charts generated;

6. Review Noise detail chart and estimate the D_{max} value (1.8D, see Figure 4).

In summary, several methods were described for estimation of scanner D_{max} value - all based on measurements of Kodak Q13 step wedge. Both simple and more elaborated methods provided $D_{max} = 1.8D$ for the Microtek 5800 scanner. The conclusion is that this scanner is almost equal to the average monitor D_{max} , but for more critical work some detail in shadows may be lost. One more thing to mention is that the estimated D_{max} of 1.8 is significantly lower than the stated in the product brochure, but this may be due to the age of the scanner - 4 years.

3. SCANNER CALIBRATION, CHARACTERIZATION, AND PROFILING

Terms such as scanner calibration, characterization, and profiling are sometimes used interchangeably with profiling being the most common meaning in the context of scanners and color management. To be consistent with conventional digital photography terminology, scanner calibration as described here

may differ from descriptions found in "scanner" literature.

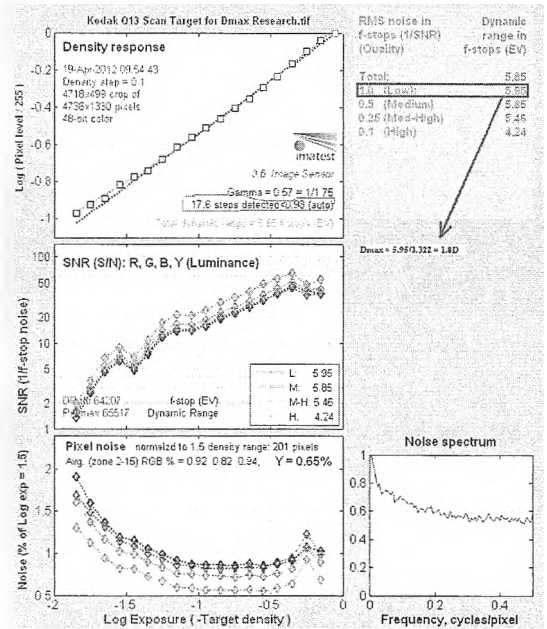


fig.4: Noise detail chart and estimate the D_{max} value

Calibration - by analogy to display devices, should result in a device being in normalized, standard, and predictable state. However, in contrast to displays, scanners are always driven by software through the manufacturer specific software drivers. Thus it may be sometimes difficult to set scanner to a desired and defined state. Sufficiently calibrated state is often achieved by turning off (in software or driver) any features that adjust black and white points, compensate for color cast, white balance, or somehow automatically adjust the image appearance. Sharpening feature should be also turned off to ensure reproducible results.

Scanner characterization - is a process of finding a mapping function between scanner RGB values and device independent color space such as CIELAB. The transform is typically built by using mathematical techniques.

The profile, software is used to describe the device's full color range capabilities. The gamut of the device is determined by measuring the RGB values for a set of known color patches. Measured data is then used to generate input profile for the device.

Profiles are then applied to an image in order to calculate RGB values for a defined color space. Typical scanner profiling process involves scanning a reference target that has numerous color patches. IT8 and HTC are examples of such reference standards. Software is used to compare the color reference values that accompany the target with the measured values. Profiling and characterization do not change the behavior of the scanner (same as for monitors).

Scanner profiling - It is of the utmost importance to have a control over all the device variables that can affect its color performance. With scanners, while light source and internal optics are controlled quite well, it is the software that is the major source of performance inconsistency. In technical terms, scanner profiling aims to ensure that raw RGB values captured by the scanner are consistently translated into standard color space such as CIELAB or CIEXYZ. Rules for such translation come from "calibrating" the raw input data to experimental data recorded in scanner target (e.g. IT8). In other words, the RGB signals acquired from a scanner (raw RGB) are related to a spectral or colorimetric representation (read patches in scanning target) through the process of scanner profiling. Typical approaches create a scanner profile by scanning a target containing a set of color patches. The target is simultaneously measured with a color measurement device to obtain spectral or colorimetric measurements in CIELAB color system. We will start with Profile Maker 5.0 module to get a profile created. In order to create the scanner profile we will use the X-rite Eye-One Scan target 1.4 [4]:

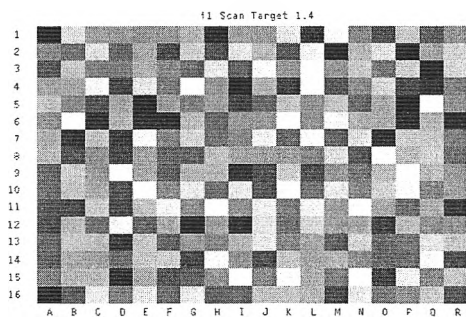


fig.5: X-rite Eye-One Scan target 1.4

The target is printed on special glossy photo paper in lab conditions and comes with reference files, de-

scribing the color coordinate of each patch in RGB system.

Next we scan the target on the profiled scanner. It is important to set the settings in the setup window correctly, i.e. no gamma, brightness and color corrections etc:

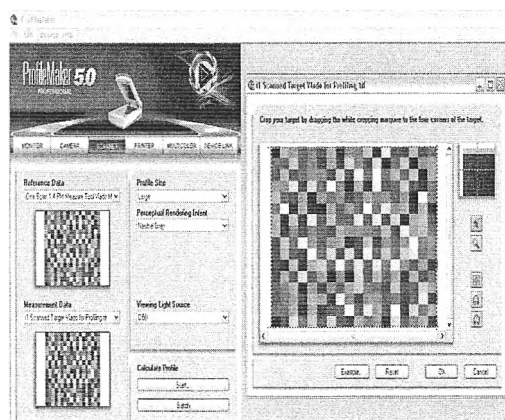


fig. 6 Scheme about gamma, brightness and color corrections

Now the scanner is successfully profiled!

4. RESULTS OF SCANNER PROFILING AND PROFILE EVALUATION. OBJECTIVE TESTS - OBTAINING CIEDE2000 COLOR DIFFERENCES:

First examples include data generated from a simple comparison of Lab values predicted by the profile (A) and LAB values reported in the profiling target reference files (B). We will use the scanner target (Eye-One Scan Target 1.4) to profile scanner and then use the scanned values of the very same target (for which LAB values are known) to validate the profile. To get data (A), scan the physical reference target and save resulting scan as *tiff* file. Reference file (B) is usually provided by the target manufacturer. It is the text file which can often be downloaded from the web or just measured by spectrophotometer (e.g., Eye One-Pro). There are several tools to perform such comparison.

4.1. Profile Maker 5.0 Software Results [6]:

Now, having both the generated LAB file of the scanned target embedded with the created scanner profile and the reference target file, measured in LAB

with Eye-One Pro available, open the Profile Maker 5 Measure Tool and launch the Calculating module. Open both files in the appropriate windows and inspect the color differences:

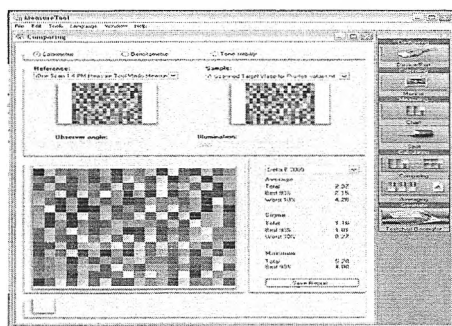


fig.7: Profile Maker 5

Take notice at the obtained Delta E 2000 color difference values. Delta E = 5 is normally considered acceptable for most applications. In our case the average is 2.37, which suggests the profile color prediction is quite accurate.

4.2. Patch Tool - Babel Color Software Results [5]:

Another tool fully capable of providing comparison of predicted and reference state for scanner targets is the Patch Tool application and its integrated module – Gamut Tools. The goal here is the same as in the above comparison – to compare the color coordinates of the scanned target, derived in LAB space using the created scanner profile, and the LAB values of the original scan target, measured with spectrophotometer Eye-One Pro. In other words we compare the actual LAB values of the original scan target with the LAB values, predicted by the scanner profile we created, followed by a comparison of the profile accuracy in Delta E 2000 units:

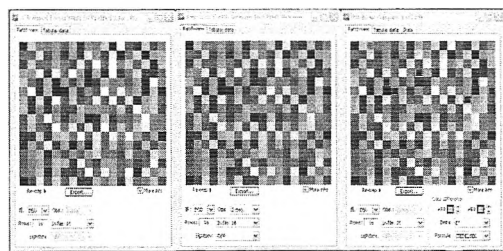


fig.8 Comparison of the profile accuracy in Delta E 2000 units

The patch displays on the figure are in the following order from left to right: 1. patch coordinates of the scanned target with embedded scanner profile, expressed in LAB values; 2. measured reference values in LAB coordinates of the original scanner target; 3. Graphical comparison between the two, using the Delta E 2000 criteria.

After some arrangement the following figures present the results in:

1. Graphical form, where the greatest delta E difference patches are situated to the left-most side;
2. Tabular data of all patches and the corresponding color difference, starting with red for delta E >5 and yellow for delta E >3;
3. Statistical representation of the data, where it is clearly seen that the majority of color errors are in the 0 to 2.5 delta E interval, which is very acceptable:

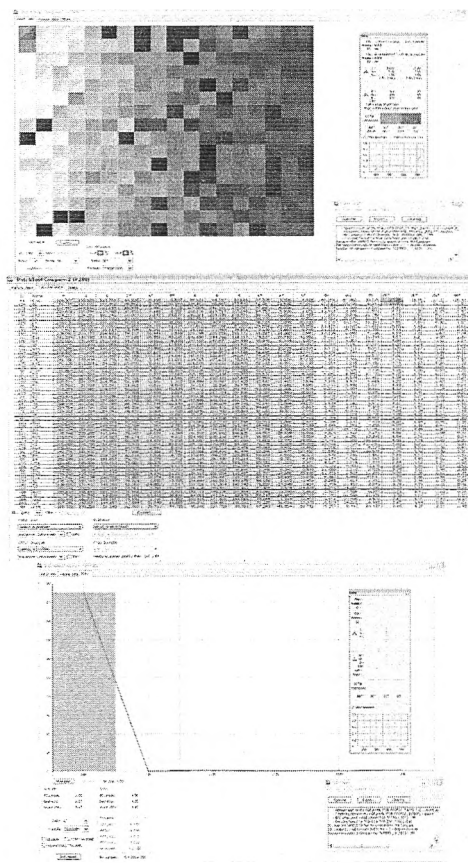


fig.8: Comparison of the profile accuracy in Delta E 2000 units

4.3. ColorThink Pro – CHROMiX Software Results:

ColorThink Pro software provides basic as well as detailed reports and visualization. As in the previous examples a file containing raw RGB values, scanner profile, and reference LAB values are needed. To obtain the desired delta E2000 color differences between the scan target and the scanned image of the same target, you need to specify the color management profile of the scanner. After all it is the performance of the profile, we created, that we are evaluating. To do so, open in Color Think Pro the file containing the Color values in LAB extracted from the scanned image of the scan target. Tell the software to assign these values to the scanner profile you just created. Next open the Eye One Scan Target 1.4. Reference txt file containing LAB description of the target without any color profile embedded. Now we are ready to evaluate the color difference between patches of the reference scan target and the real patch colors, as predicted by the scanner profile, we are evaluating. Fig.9 shows the preliminary results and setups described.

Here is the 3D representation of the Delta E 2000 color differences between the reference values and the scanned patches and the scanned patches assigned with the scanner profile, being evaluated.

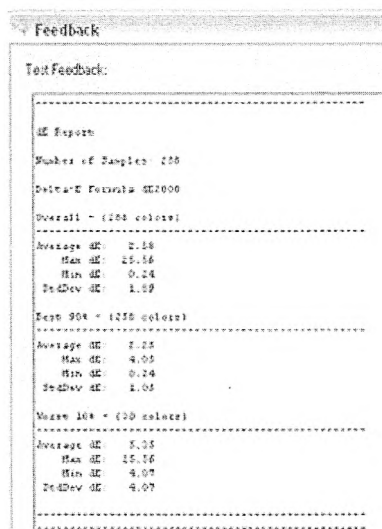


fig.9: Preliminary results and setups

The color notation follows the list of color differences above: red is Delta E>5, yellow is >3 and green is >0.5. The vectors denote the direction of color difference change from scanned values to the reference values. One should also take into account the rendering intent, which deals with out of gamut colors. In our case we use relative colorimetric intent:

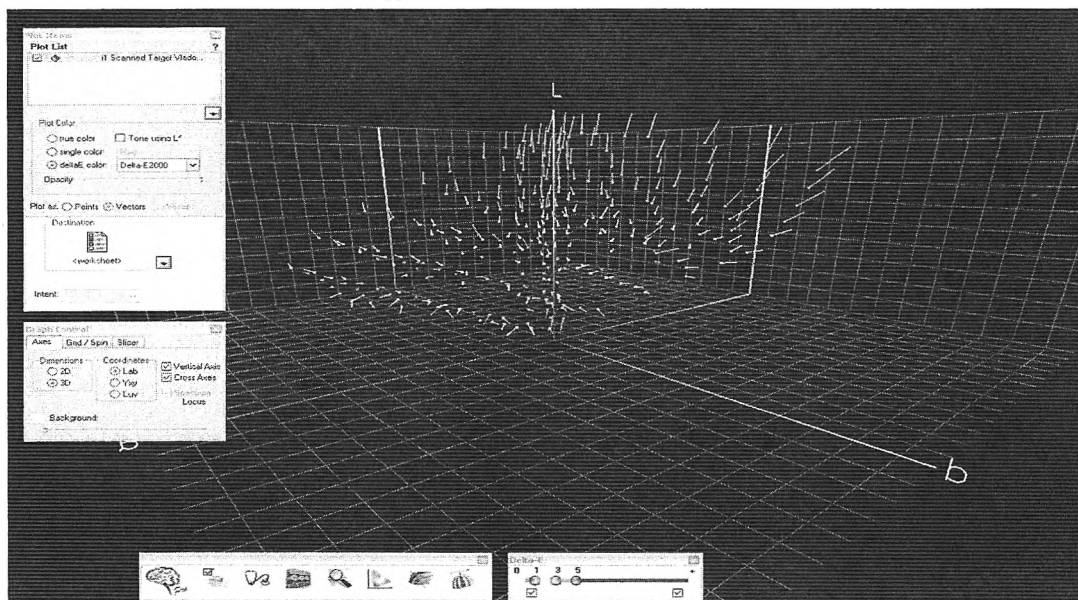


fig.10 3D representation of the Delta E 2000 color differences between the reference values and the scanned patches

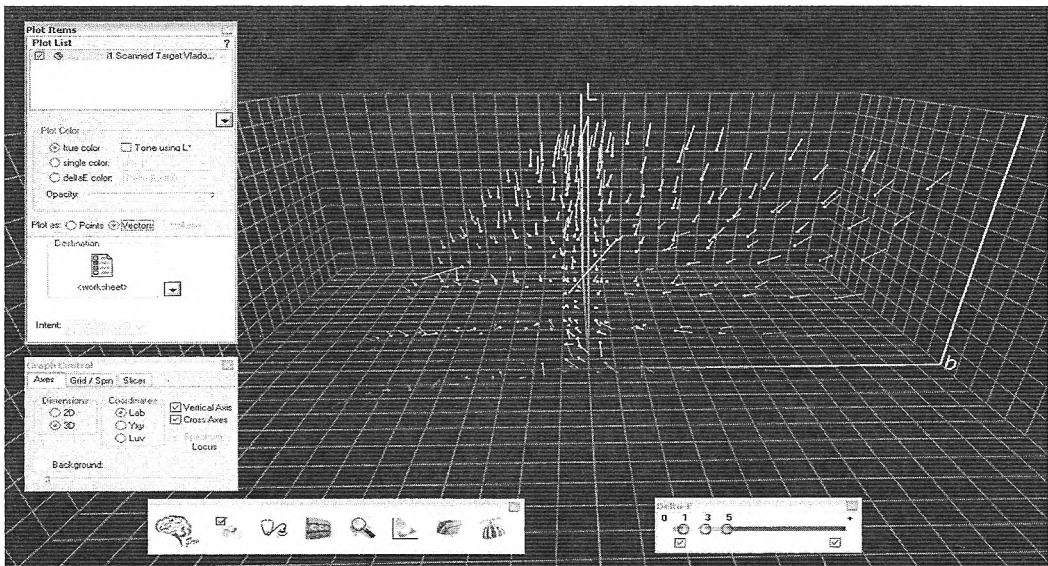


fig.11: Graphically the actual colors, their position in LAB space and the Delta E 2000 color difference vectors of change

5. SUMMARY (OBJECTIVE ANALYSIS)

1. When same target is used for profiling and evaluation, the lowest (best) DE2000 and DE2000(max) values are obtained. For example, profiling scanner using Eye One Scan Target 1.4 target leads to a profile which when assigned to the scanned image of the very same Eye One Scan Target 1.4 gives excellent results in terms of LAB color differences (CIEDE2000).

2. On the other hand, profiles created from one type of a target show higher DE2000 values when assigned to images of other targets. For example, profiling scanner using IT8.7/2 target leads to a profile which when assigned to a scanned image of Eye-One Scan Target 1.4 (ST1.4) results in about four times as high DE2000 and DE00 max as if the same target would be used.

3. In general, profiles created from any targets used above provide significantly higher DE2000 (D2000max) values when assigned to Gretag Macbeth ColorChecker. This suggests that texture of the reflective substrates and colorants play a significant role when scanning different media.

4. The highest obtained Delta E 2000 difference of over 21 units is probably due to measurement error of the reference target, however the observed color differences in the light pastel tones (almost all of

them) is not a coincidence and may be caused by the limited color gamut of the scanner in the light tones, or it could simply be due to dirt in the optical system of the scanner.

Credits

In accordance to the authors' science project of evaluating the quality of office color printers, sponsored by the Bulgarian Science Research Fund, the following article will investigate a part of the "jungle" of color management and its implementation in color quality evaluation of scanners.

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