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# Comparison of ICC and DNG colour profile workflows based on colorimetric accuracy

Jure Ahtik

University of Ljubljana, Faculty of Natural Sciences and Engineering,  
Snežniška 5, SI-1000 Ljubljana, Slovenia

jure.ahtik@ntf.uni-lj.si

## Abstract

Managing colours is important for every photographer. In this paper, two of the solutions were described and researched: ICC colour profiles and DNG colour profiles. While ICC is a well-established and commonly used option, there are some disadvantages when it comes to time, price, and understanding; DNG colour profiles offer us a good response to these disadvantages but as a result the quality of colour corrections is lower. This paper gives the exact answers on how big the colour difference between both processes is and what the cases are when the use of ICC or DNG colour profiles is advised. The main focus of the research is a usability of both workflows.

**Keywords:** digital photography, colour management, colour reproduction, colour test chart, white balance

## 1. Introduction

Making a workflow faster, better and more efficient should be a goal for every professional. It is the same when it comes to colour management and photography. Solutions can be hard to understand, time-consuming, not standardised or too expensive, but implementing them into the workflow can reflect itself in a better and more manageable process (X-rite, 2017a). We can find different solutions for colour management on the market. Most commonly used and in many fields standardised possibility is using ICC colour profiles (Ashe, 2014; International Color Consortium, 2016; International Organization for Standardization, 2009; Green, 2010). When implemented into our workflow, ICC colour profiles give us an all-around solution for managing colour reproduction as they cover every step of the process: photography, scanning, printing and viewing on a display (Jackson, 2015; Green, 2010) – for all of these technologies there is a way how to measure, describe and calculate colour corrections necessary to manage and improve colours (RGB, CMYK or multichannel) on the reproduction (Ashe, 2014; Qu and Gooran, 2013). The ICC colour profiles are well-known, commonly used and in many cases the only or by far the best option (Ashe, 2014; International Color Consortium, 2016).

Photography and ICC colour profiling is a field of its own. For managing colours that way, a photographer

has to use expensive equipment (colour target and special software, for example *X-rite Eye-One Match 3*). The procedure is to take a photo of a test chart in a controlled environment, measure the colour patches of the acquired picture and compare the measurements to the stored values. Comparing the measurements and calculating the colour corrections give us the ICC colour profile that we can use to correct colours on photos taken under the same conditions that were used when making the ICC colour profile. The procedure is time-consuming and requires expensive equipment (Beretta, et al., 2011). We have to repeat the whole procedure for every time lightning conditions or exposure settings change (International Color Consortium, 2016; Penczek, Boynton and Splett, 2014). That's why photographers are using it mostly in controlled environments, such as photography studio.

In 2004 Adobe introduced a DNG (digital negative) image file format (Adobe, 2012). The main goal was RAW format standardization as the market offers many different, company based solutions. Adobe also wanted to offer the best format for archiving digital photos; DNG could be a common way of storing RAW image data from all camera manufacturers (Adobe, 2012). Main disadvantage of the current diverse situation is the constant need of software upgrades to have support for all the new formats that appear on the market. Old software versions often get obsolete as the company

stops releasing upgrades for them and photographers are forced into expensive upgrading. Although DNG was introduced as an open standard, it is being adopted by just a few camera manufacturers. Market penetration is slower than expected. In 2008 Adobe upgraded DNG standard to version 1.2.0.0 that includes support for colour management. The other way of colour correction in photography was born; we call it DNG colour profile (Adobe, 2012). The procedure of making a DNG colour profile is very similar as when making an ICC colour profile, but it's faster and easier to use and it requires less investment in the equipment.

This paper compares both of the mentioned methods – ICC and DNG colour profile based colour management. The purpose of this research is to find out if DNG colour profiles can compete with ICC colour profiles when it comes to colour reproduction.

## 2. Methods

The procedure of making a colour description (or a colour profile) of a device (for example digital camera) and using it, consists of following steps:

1. setting the photography scene,
2. choosing the colour test chart,

3. acquiring the colour test chart,
4. measuring the acquired data,
5. comparing the acquired data to stored values (predictions),
6. calculating the correction matrix,
7. saving the calculations into the colour profile,
8. applying the colour profile on the acquired data (for example a photo).

For all of the listed steps we have different options from which we can choose from. In the research, the steps from 4 to 7 were questioned as variables. Those steps are really the procedure of how to make a colour profile. Test chart, a method of acquiring it, and a way of using it, were constant for both of the research methods.

### 2.1 Choosing the colour test charts

There are many different colour test charts available and used but one of them has become a part of most of the similar researches. *ColorChecker* is a test chart standard made by X-rite that is widely used for different kinds of colour control. It is included in many of the market solutions, sometimes by its own and sometimes as a part of a bigger colour pallet (X-rite, 2017b). *ColorChecker* consists of 24 colour patches that are divided into four groups (Table 1): natural colours, miscellaneous colours, primary & secondary colours, and

Table 1: *ColorChecker* basic values, adopted from Poynton (2008)

Colours	Number	Description	Munsell notation	CIE xyY	sRGB D65 colour values
<b>Natural</b>	1	Dark skin	3 YR 3.7/3.2	0.400 0.350 10.1	#735244
	2	Light skin	2.2 YR 6.47/4.1	0.377 0.345 35.8	#c29682
	3	Blue sky	4.3 PB 4.95/5.5	0.247 0.251 19.3	#627a9d
	4	Foliage	6.7 GY 4.2/4.1	0.337 0.422 13.3	#576c43
	5	Blue flower	9.7 PB 5.47/6.7	0.265 0.240 24.3	#8580b1
	6	Bluish green	2.5 BG 7/6	0.261 0.343 43.1	#67bdaa
<b>Miscellaneous</b>	7	Orange	5 YR 6/11	0.506 0.407 30.1	#d67e2c
	8	Purplish blue	7.5 PB 4/10.7	0.211 0.175 12.0	#505ba6
	9	Moderate red	2.5 R 5/10	0.453 0.306 19.8	#c15a63
	10	Purple	5 P 3/7	0.285 0.202 6.6	#5e3c6c
	11	Yellow green	5 GY 7.1/9.1	0.380 0.489 44.3	#9dbc40
	12	Orange yellow	10 YR 7/10.5	0.473 0.438 43.1	#e0a32e
<b>Primary and secondary</b>	13	Blue	7.5 PB 2.9/12.7	0.187 0.129 6.1	#383d96
	14	Green	0.25 G 5.4/9.6	0.305 0.478 23.4	#469449
	15	Red	5 R 4/12	0.539 0.313 12.0	#af363c
	16	Yellow	5 Y 8/11.1	0.448 0.470 59.1	#e7c71f
	17	Magenta	2.5 RP 5/12	0.364 0.233 19.8	#bb5695
<b>Greyscale</b>	18	Cyan	5 B 5/8	0.196 0.252 19.8	#0885a1
	19	White	N 9.5/	0.310 0.316 90.0	#f3f3f2
	20	Neutral 8	N 8/	0.310 0.316 59.1	#c8c8c8
	21	Neutral 6.5	N 6.5/	0.310 0.316 36.2	#a0a0a0
	22	Neutral 5	N 5/	0.310 0.316 19.8	#7a7a79
	23	Neutral 3.5	N 3.5/	0.310 0.316 9.0	#555555
	24	Black	N 2/	0.310 0.316 3.1	#343434

greyscale colours (Poynton, 2008). Some of the colours are chosen from the graphic standards, others are taken from the environment and all are equally distributed in the chromaticity diagram (Figure 1). Values are publicly available.

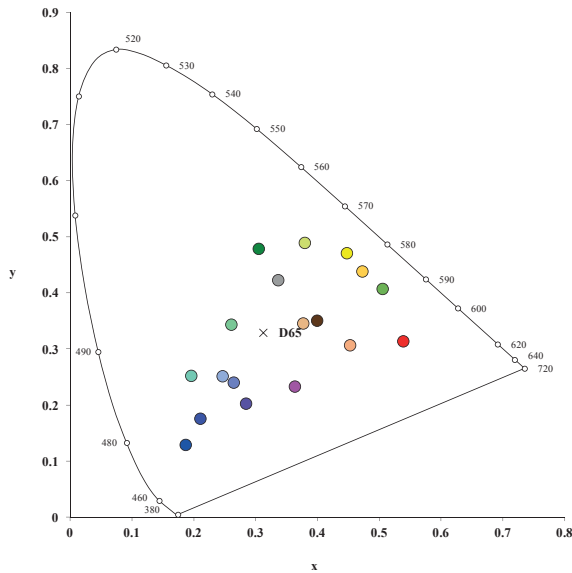


Figure 1: Distribution of colours included in the ColorChecker test chart shown in a chromaticity diagram adopted from Poynton (2008)

In the research, two of the available market solutions were used:

- *ColorChecker Digital SG*: it includes 140 colour patches (24 of the basic *ColorChecker* included); its main purpose is use in digital photography as it equally covers most of the digital camera colour gamut (X-rite, 2017b),
- *ColorChecker Passport*: this is a small and portable colour test chart that includes basic 24 *ColorChecker* patches and different patches for white balance control; it is designed specifically for making DNG colour profiles. Test chart comes with a designated software that can be used with other *ColorChecker* test charts as well (X-rite, 2017b).

## 2.2 Acquiring the data (taking a photo)

The procedure of acquiring data for the research was taking a photo of the test chart in a controlled environment in a dark photography studio with no additional light sources (Figure 2). Equipment used:

- *ColorChecker Digital SG* test chart,
- Nikon D700 digital camera (exposure time 1/250 s and ISO speed 100; as we used RAW workflow we were able to set white balance later in the process),

- AF-S NIKKOR 50mm/1.4G camera lens (aperture 5.6),
- two Quantum Q1250 halogen studio lights with soft-box mounted (CCT 3100 K, CRI 100, power 1 000 W, and 1-meter distance from the test chart under the 45° and -45° angles),
- tripod.

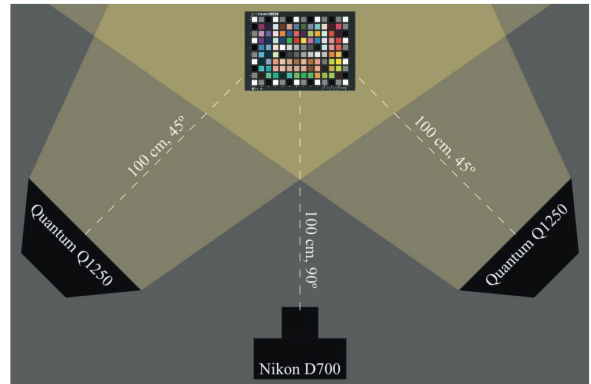


Figure 2: Photography set-up for acquiring a ColorChecker SG test chart

## 2.3 Making an ICC colour profile

The ICC colour profile was made with an acquired photo of a *ColorChecker Digital SG* test chart. The *X-rite Eye-One Match 3* software with *X-rite Eye-One Pro* spectrophotometer plugged in (it works as a licence hardware key for the software) was used. Before a photo of a test chart was opened in the software it was converted from NEF (Nikon RAW format) to 24-bit TIFF (using *Adobe Camera Raw 6.7* and *Adobe Photoshop CS5*), white balance was set the to 3 100 K (equal as the light source used) and the pre-attached sRGB colour profile was excluded (choosing the “Don’t colour manage” option in *Adobe Photoshop CS5*). *X-rite Eye-One Match 3* recognized the test chart on a photo and calculated the ICC colour profile automatically (Figure 3).



Figure 3: X-rite Eye-One Match 3 application with a photo of a ColorChecker Digital SG test chart

## 2.4 Making a DNG colour profile

The DNG colour profile is a colour description of a particular digital camera, regardless the type of light source we use when taking photos. This colour profile can include two conversion matrices for colour conversion – one for CIE standard illuminant A and one for D65, where values in-between both are being interpolated based on the indicated colour temperature of the used light source. Adobe offers such profiles for most of the digital cameras on the market and in most cases correction is done very well.

Better colour correction for a particular light source, such as light source used in this research, can also be done. In this case, a RAW digital data was used of a photo of the *ColorChecker Digital SG* test chart and *X-rite ColorChecker Camera Calibration 1.1.0* application that is provided together with the *ColorChecker Passport* test chart.

For the purpose of the research the same test chart was used in both cases – ICC and DNG. Application automatically chooses the 24 basic *ColorChecker* patches (Figure 4) and creates the DNG colour profile.

While the profile was generated by using the photo, white balance value was set by hand (in our case 3100 K).

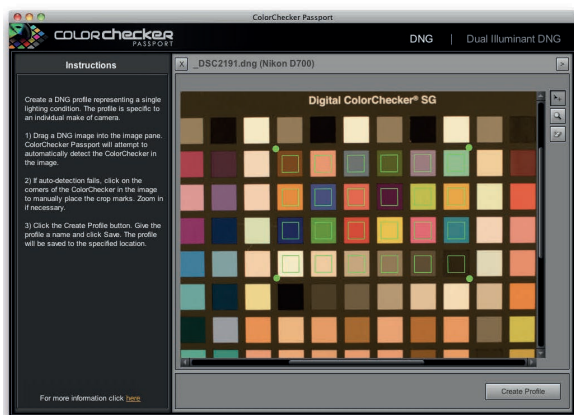


Figure 4: X-rite ColorChecker Camera Calibration 1.1.0 application with a photo of a ColorChecker Digital SG test chart

## 2.5 Comparison of both profiles

The comparison of both profiles was done in the following steps:

- measuring CIELAB values of 24 *ColorChecker* patches on *ColorChecker Digital SG* test chart (to obtain the real values as the chart was not brand new at the moment of the research and

the values provided by X-rite could not be trusted anymore); X-rite EyeOne Pro spectrophotometer and *GretagMacbeth KeyWizard 2.5* application (standard CIE illuminant D50 and 2° standard observer) was used,

- applying the ICC colour profile on a photo of the *ColorChecker SG* test chart; by using *Adobe Photoshop CS5*,
- applying the DNG colour profile on a photo of the *ColorChecker SG* test chart; by using *Adobe Photoshop CS5*,
- colour picking CIELAB values of 24 *ColorChecker* patches on both photos using *Adobe Photoshop CS5*,
- calculating colour differences  $\Delta E^*_{ab}$ ,  $\Delta L^*$ ,  $\Delta a^*$ , and  $\Delta b^*$  between measured CIELAB values on a real-life *ColorChecker SG* test chart and those from corrected photos – for ICC and DNG.

The main method of describing the differences was based on  $\Delta E^*_{ab}$  as it is a widely used method for this kind of research (Sharma, 2006). The other possible method would be comparing colour gamuts of both profiles as some researches use (Deshpande, Green and Pointer, 2015; El Saleh, Filicetti and Sharma, 2016). The CIELAB colour space is based on C<sub>1931</sub> that is in this case based on an average 2° observer and standard CIE illuminant D50 (normalised colour values).

## 3. Results and discussion

Results show us small to very big colour differences between real values and values obtained after the calibration. Average colour difference is 5.05 for values corrected with an ICC colour profile (Table 2) and 7.59 for values corrected with a DNG colour profile (Table 3). An ICC colour profile did a better job which was expected because 140 colour patches were used to make a profile (just 24 for a DNG colour profile).

What is surprising is, that the difference between both results is not so big – just a 2.54 colour difference between average values of all measured colours. If we take a look at CIE  $L^*$ ,  $a^*$ , and  $b^*$  colour values, we can observe that the difference between an average  $\Delta L^*$  is 1.12,  $\Delta a^*$  is 0.30, and  $\Delta b^*$  is 0.62. A lot better results were expected in favour of ICC where a more complex and advanced procedure is used to make the colour profile.

When we look at different colours we can observe that some of them were not reproduced very well in both cases, ICC and DNG. Cyan, purplish blue and blue were the worst in both cases (Table 4). This can be explained with the illuminant used: spectral distribution of the halogen studio lighting was very similar to standard

illuminant A, where we can observe a low emission in a first part of the visible spectrum and a very high emission in the last part of the visible spectrum.

Looking at the data we can also observe that greyscale colours were reproduced best in both workflows. That was expected because greyscale patches have none or very low chromatic values so the colour differences appeared almost only because of the change in lightness. Slightly better results were achieved with an ICC colour profile. For all the other colours, there isn't any significant pattern that would strongly correlate both methods (Pearson correlation is 0.74, Spearman correlation of ranked values is just 0.48 - correlations were calculated between  $\Delta E^*_{ab}$  values of both methods).

We can see that the overall quality of the reproduction is better when we use an ICC colour profile but when it comes to usability of both workflows, a DNG colour

profile has more advantages. First is photographing the test chart. The best and also easier way to do it is by using *ColorChecker Passport* which is a pocket-sized test chart that is not hard to lit equally. Equally lit test chart is one of more important steps in the first phase of the process and the bigger the chart is, the more precise the lightning condition in our photography setup has to be.

The second advantage of DNG colour profile is time. For making a DNG colour profile we can use *Adobe Photoshop* or *Adobe Lightroom* plugins that offer us a possibility to make profiles in a very short time (Schewe, 2012). These plugins are also available for free. Shorter time can be a huge plus for every workflow. And the third advantage is a possibility to have two illuminant correction matrices in a DNG colour profile that give us a possibility of more universal use of the solution.

Table 2: CIELAB values of ColorChecker patches corrected with an ICC colour profile

Colours	Number	Description	Measured ColorChecker SG			Photo + ICC colour profile			$\Delta E^*_{ab}$
			$L^*$	$a^*$	$b^*$	$L^*$	$a^*$	$b^*$	
Natural	1	Dark skin	32.77	18.16	21.10	33	14	21	4.17
	2	Light skin	63.24	20.64	19.63	65	19	15	5.22
	3	Blue sky	47.07	-5.35	-24.07	47	-3	-25	2.53
	4	Foliage	38.56	-16.62	29.95	38	-17	38	8.08
	5	Blue flower	51.99	8.77	-26.86	52	11	-27	2.23
	6	Bluish green	69.42	-34.11	-0.05	70	-31	0	3.16
Miscellaneous	7	Orange	60.73	38.16	71.32	61	40	68	3.81
	8	Purplish blue	36.42	10.37	-49.48	44	17	-54	11.04
	9	Moderate red	47.59	51.98	19.65	48	51	16	3.80
	10	Purple	21.98	28.25	-27.15	19	32	-26	4.93
	11	Yellow green	71.12	-23.93	64.96	71	-24	74	9.04
	12	Orange yellow	69.88	19.91	78.62	69	22	78	2.35
Primary and secondary	13	Blue	20.73	20.12	-57.22	14	27	-61	10.34
	14	Green	52.84	-43.26	38.72	54	-38	35	6.55
	15	Red	37.28	63.16	39.99	36	63	32	8.09
	16	Yellow	81.01	3.92	88.71	80	6	92	4.02
	17	Magenta	48.53	54.22	-15.69	49	56	-15	1.97
Greyscale	18	Cyan	48.47	-32.69	-29.64	49	-18	-34	15.33
	19	White	97.24	-0.71	1.48	93	1	-1	5.20
	20	Neutral 8	79.77	0.01	0.10	80	1	-1	1.50
	21	Neutral 6.5	65.82	-0.21	-0.03	66	1	-1	1.56
	22	Neutral 5	50.47	-0.11	0.52	51	1	-1	1.96
	23	Neutral 3.5	36.08	-0.25	-0.16	35	0	-2	2.15
	24	Black	17.69	-0.40	-1.02	17	0	-3	2.13

Average colour difference  $\Delta E^*_{ab}$ : **5.05**

Average colour difference  $\Delta L^*$ : **0.24**

Average colour difference  $\Delta a^*$ : **2.12**

Average colour difference  $\Delta b^*$ : **1.06**

Pearson correlation between measured and reproduced  $L^*$  values: **0.99**

Pearson correlation between measured and reproduced  $a^*$  values: **0.99**

Pearson correlation between measured and reproduced  $b^*$  values: **1.00**

Table 3: CIELAB values of ColorChecker patches corrected with a DNG colour profile

Colours	Number	Description	Measured ColorChecker SG			Photo + DNG colour profile			$\Delta E^*_{ab}$
			$L^*$	$a^*$	$b^*$	$L^*$	$a^*$	$b^*$	
Natural	1	Dark skin	32.77	18.16	21.10	33	18	23	1.92
	2	Light skin	63.24	20.64	19.63	69	22	12	9.66
	3	Blue sky	47.07	-5.35	-24.07	47	-1	-32	9.05
	4	Foliage	38.56	-16.62	29.95	37	-18	38	8.32
	5	Blue flower	51.99	8.77	-26.86	54	13	-31	6.25
	6	Bluish green	69.42	-34.11	-0.05	72	-25	-7	11.75
Miscellaneous	7	Orange	60.73	38.16	71.32	66	33	76	8.74
	8	Purplish blue	36.42	10.37	-49.48	33	22	-63	18.16
	9	Moderate red	47.59	51.98	19.65	52	54	22	5.39
	10	Purple	21.98	28.25	-27.15	19	30	-25	4.07
	11	Yellow green	71.12	-23.93	64.96	74	-25	73	8.61
	12	Orange yellow	69.88	19.91	78.62	74	14	84	8.99
Primary and secondary	13	Blue	20.73	20.12	-57.22	17	36	-69	20.12
	14	Green	52.84	-43.26	38.72	54	-45	40	2.45
	15	Red	37.28	63.16	39.99	43	63	37	6.46
	16	Yellow	81.01	3.92	88.71	83	1	91	4.21
	17	Magenta	48.53	54.22	-15.69	54	58	-14	6.86
	18	Cyan	48.47	-32.69	-29.64	49	-17	-43	20.61
Greyscale	19	White	97.24	-0.71	1.48	94	1	-1	4.42
	20	Neutral 8	79.77	0.01	0.10	83	1	-1	3.55
	21	Neutral 6.5	65.82	-0.21	-0.03	70	1	-1	4.46
	22	Neutral 5	50.47	-0.11	0.52	52	1	-1	2.43
	23	Neutral 3.5	36.08	-0.25	-0.16	34	1	-2	3.05
	24	Black	17.69	-0.40	-1.02	16	0	-3	2.63

Average colour difference  $\Delta E^*_{ab}$ : **7.59**

Average colour difference  $\Delta L^*$ : **1.36**

Average colour difference  $\Delta a^*$ : **2.42**













Average colour difference  $\Delta b^*$ : **1.68**

Pearson correlation between measured and reproduced  $L^*$  values: **0.99**

Pearson correlation between measured and reproduced  $a^*$  values: **0.98**

Pearson correlation between measured and reproduced  $b^*$  values: **1.00**

Table 4: Visual presentation of the worst six reproduced colours for ICC and DNG workflows (approximate colour rendering, based on the data from Tables 2 and 3)

Colour profile	Colour patch					
	Cyan	Purplish blue	Blue	Yellow green	Red	Foliage
ICC						
DNG						

#### 4. Conclusion

The use of ICC colour profiles is a better solution than DNG when it comes to colorimetric accuracy of the reproduction. In almost all measured colour patches better results were achieved with ICC so the altogether measurements were also better. On the other hand, ICC

colour profile requires more time, expensive equipment, and it only offers us a solution to make a colour profile for each illuminant separately, whereas DNG profiling is faster, cheaper, and with a possible use of two illuminants also more universal. We can conclude that both workflows have their advantages but because of its usability the DNG colour profiles would

be recommend for most photographers. Surprisingly, the quality is not so much lower when using DNG colour profiles and such a small colour difference is for most photography scenarios something a professional can live with. Photography conditions are in most cases not so constant that the 2.54 average colour difference would make a significantly worse result that could be easily seen with the naked eye. In cases where

we make reproductions of an artwork, where perfect colour reproduction is needed, the use of ICC colour profiles would be recommended. These are also the scenarios where more time and resources are usually available so the higher cost should not be a big disadvantage. But in almost all modern photographic scenarios the time and money saving can make a crucial difference between getting a job or not.

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