Pyramid Imaging
945 East 11th Avenue Tampa, FL 33605
Phone: (813) 984-0125
Contact: Sales@ pyramidimaging.com
https://pyramidimaging.com

chromasens
Imaging for Professionals

Application specific color calibration with truePIXA

Whitepaper

Version	Author(s)	Date
R1	Timo Eckhard, Sebastian Georgi	18.12.2017

Executive Summary:

The aim of this work is to illustrate the dependence of measurement performance of multi-spectral imaging systems on the type of color calibration used. For application-specific color calibration, high performance can be achieved. If a non-adequate color calibration is used, the measurement performance might drop considerably. These effects are demonstrated empirically by means of textile and paper measurement applications. The underlying theory for the measurement performance drop is explained briefly.

1. Introduction

The line-scanning based multi-spectral camera truePIXA is a measurement device for fast pixel-wise spectral and colorimetric information from scan surfaces (ie. spectral reflectance or CIE-Lab color coordinates respectively) [1].

By means of the multi-spectral imaging principle, various spectral image channels are acquired by the system, typically more than 3 as compared to conventional RGB cameras. In case of the truePIXA camera system, 12 distinct spectral image channels are acquired in the visible range of the light spectrum. A color calibration algorithm is then used to transform the spectral image information to the desired output image format, for instance a 3-channel CIE-Lab image. This conversion is very much tailored to specific spectral properties of the material that is to be measured using the multi-spectral camera system.

For certain groups of materials, assumptions can be made and color calibration can be generalized. That means that a color calibration for one material can be used for measurement on another material. However, to figure out whether or not generalization is possible, an in-depth analysis is typically required.

Best performance with multi-spectral imaging systems is generally achieved if the color calibration is performed application specific. In this report, we show the influence of application specific color calibration on measurement performance, by example of using truePIXA image data of digital printed paper and textile substrates.

2. Application specific color calibration for multi-spectral color measurement in digital printing applications

We consider measurement of ink-jet printed samples on paper and textile substrates. For each application, a distinct, substrate-specific ink is used. Due to the physical nature of matter and light interaction of ink and substrate, the spectral properties of a certain printed sample might be different for textile or paper, even though the color appears the same to the human observer. An example as such is given in Figure 1.

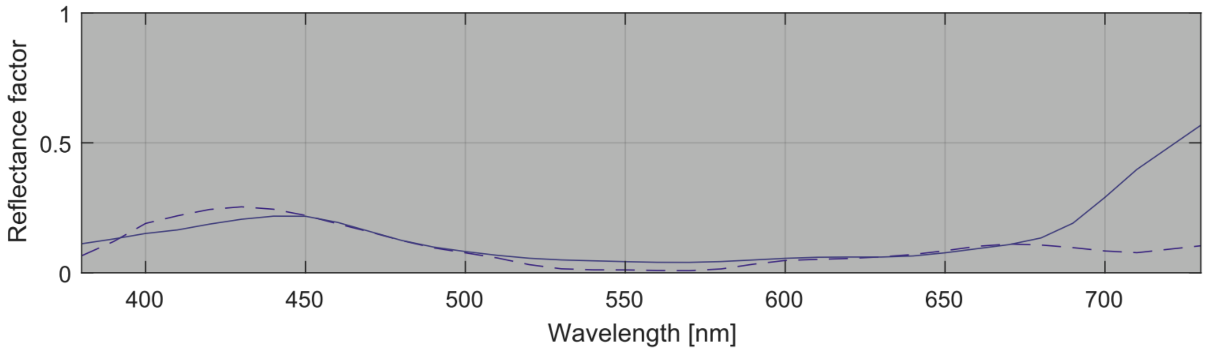


Figure 1: Spectral reflectance curves of blue colored patch on textile substrate (solid line) and paper substrate (dashed line). A large difference between the curves is apparent at wavelengths larger 660nm.

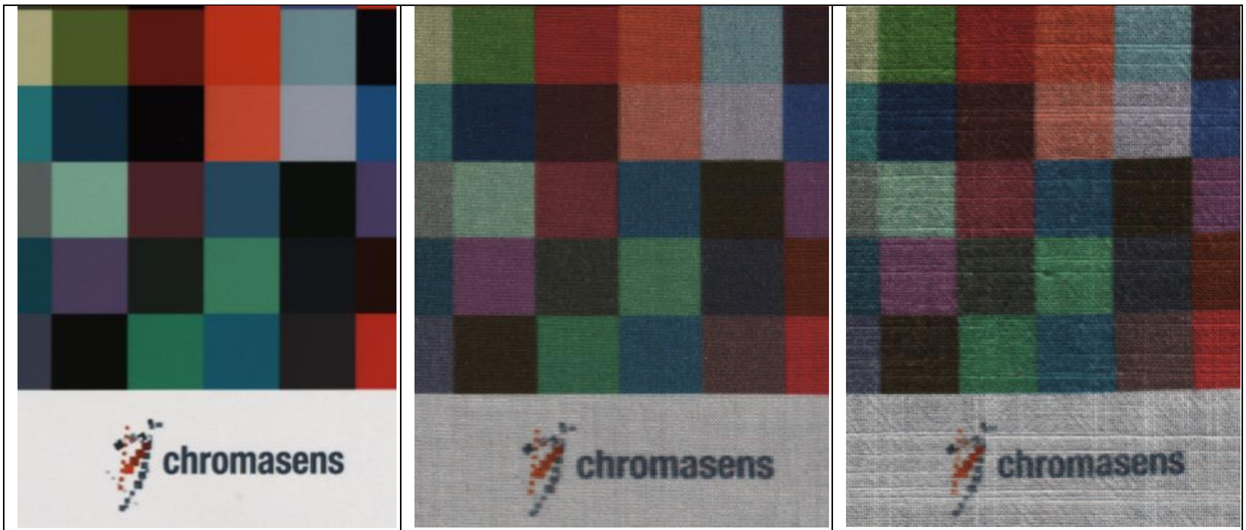
The color calibration of a truePIXA camera system accounts for such spectral differences. To achieve this, a so-called "training chart" is required. For the ink-jet printed samples, a training chart can be a regular grid of printed color patches that sample the gamut of printable colors. An example of the charts considered in this work is given in Figure 2. For each patch, spectral reference point-measurements were acquired using a spectroradiometer. We used a Konica-Minolta FD-7 [2]. Apart from spectral reference measurements, multi-spectral camera response data is required for the color calibration. The response data is extracted patch-wise from the regular grid by averaging image areas that correspond to the measurement spot of the spectroradiometric point-measurement device.

Using camera response and corresponding spectral reference measurements, color calibration can be performed with a proprietary algorithm that is accessible via truePIXA API / Chromantis GUI software.

For this work, color calibration was performed for three different substrates:

- Paper substrate
- Soft textile substrate with black backing
- Rough textile substrate with black backing

The following figure illustrates a small section of the training chart for each substrate.



Paper substrate	***Soft textile substarte***	***Rough textile substrate***

Figure 2: Partial view of the color calibration charts on different substrates.

As an example, the colorimetric and spectral properties of the patches included in the training chart for the case of paper substrate are shown in Figure 4 and Figure 4 respectively.

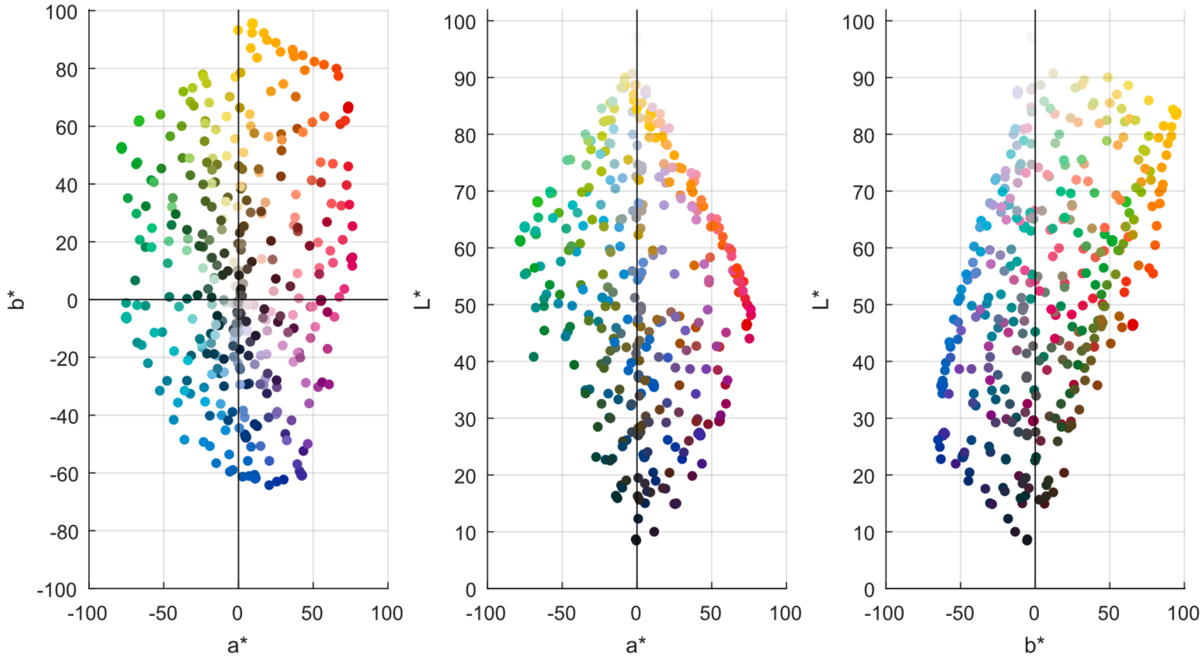


Figure 3: CIE-Lab color coordinates of color patches included in the paper substrate training chart.

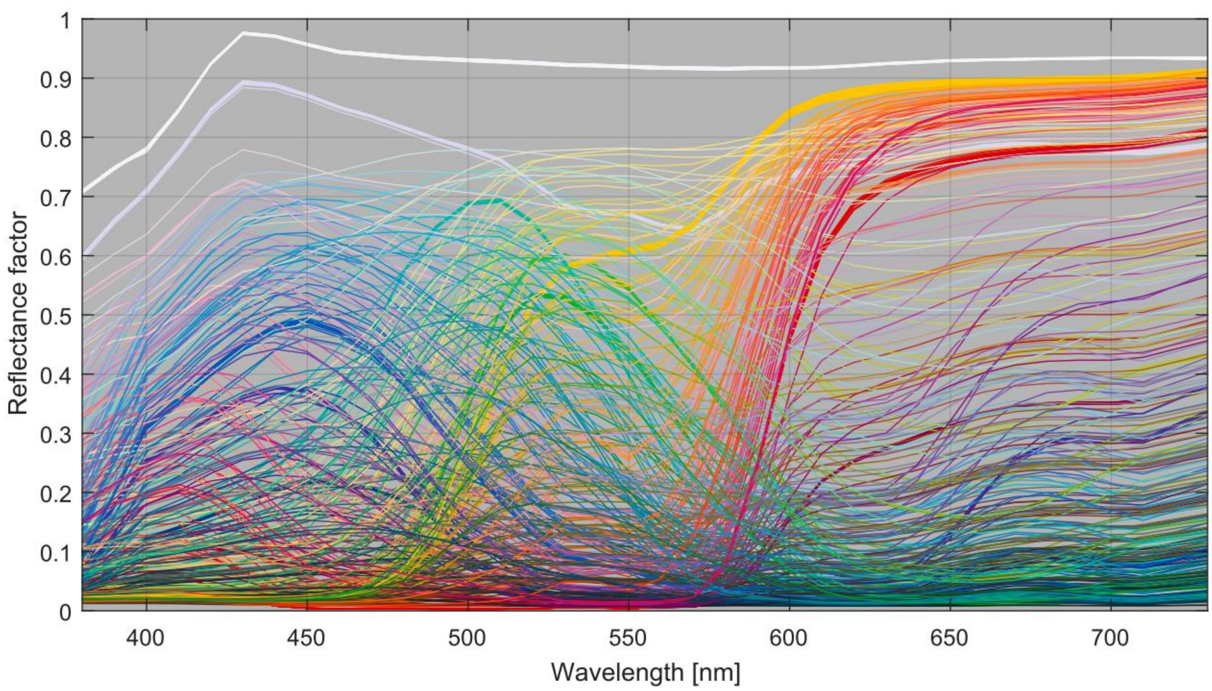


Figure 4: Spectral reflectance curves of color patches included in the paper substrate training chart.

To evaluate the performance of spectral color measurement using truePIXA, a second set of color charts with differently distributed color patches was produced on paper and textile substrates. We denote them as “test charts”. Color calibration and testing are therefore performed on distinct datasets.

The metrics considered for evaluation are spectral root mean square error (RMSE) and color difference in CIE-Lab color space (CIE-dE2000, further “dE00”) [3], which is in accordance to the latest recommendation of the CIE. Using these metrics, differences between the truePIXA measured patches and the reference measurement were computed.

2.1 Experimental findings

In what follows, first order statistics of the aforementioned metrics are used to summarize the numerical results:

(1) Calibrating with ***paper*** substrate training chart.
Testing with ***paper*** substrate test chart.

	Mean	***Std. Dev.***	***Min.***	***Max.***
RMSE	0.0077	0.0030	0.0016	0.0186
dE2000	0.53	0.31	0.08	3,92

(2) Calibrating with ***soft textile*** substrate training chart.
Testing with ***soft textile*** substrate test chart.

	Mean	***Std. Dev.***	***Min.***	***Max.***
RMSE	0.0080	0.0030	0.0020	0.0232
dE00	0.58	0.32	0.03	2.94

(3) Calibrating with ***rough textile*** substrate training chart.
Testing with ***rough textile*** substrate test chart.

	Mean	***Std. Dev.***	***Min.***	***Max.***
RMSE	0.0117	0.0056	0.0028	0.0386
dE00	0.96	0.56	0.06	3.37

(4) Calibrating with ***rough textile*** substrate training chart.
Testing with ***soft textile*** substrate test chart.

	Mean	***Std. Dev.***	***Min.***	***Max.***
RMSE	0.0106	0.0035	0.0032	0.0224
dE00	0.81	0.47	0.01	3.40

(5) Calibrating with ***paper*** substrate training chart.
Testing with ***rough textile*** substrate test chart.

	Mean	***Std. Dev.***	***Min.***	***Max.***
RMSE	0.1233	0.0302	0.0586	0.1882
dE00	3.87	1.39	0.63	12.50

Our findings are consistent for colorimetric and spectral metrics. However, for the sake of simplicity, we base the interpretation mainly on color differences. The results allow drawing various conclusions:

General measurement performance of truePIXA (Exp. 1-3)

- When color calibration is performed application-specific, high measurement performance is achieved.

Measurement performance on paper (Exp. 1) vs. soft textile substrate (Exp. 2):

- The results are comparable. Calibration was performed application specific for each substrate and high performance measurement results are achieved.

Measurement performance on soft textile (Exp. 2) vs. rough textile substrate (Exp. 3):

- Higher performance is achieved for soft textile as compared to rough textile.
- On average, dE00 is still smaller than one unit.
- The rough textile substrate is richer in texture. Judging visually, printed patches are spatially less homogeneous. It might be that the reference measurement spot does not match entirely the truePIXA measurement spot, which might explain the residual color differences.

Measurement performance on soft textile with calibration for rough textile substrate (Exp. 4):

- As compared to testing and calibration on rough textile substrate (Exp. 2), performance drops slightly.
- On average, dE00 is still smaller than one unit.
- It can be seen that there is a considerable difference when interchanging the print substrate without applying a specific color calibration.

Measurement performance on rough textile substrate with calibration for paper substrate (Exp. 5):

- As compared to testing and calibration on paper substrate (Exp. 1), performance drops considerably.
- The average color difference is so large that a human observer could easily spot differences.
- It can be concluded that under this condition, multi-spectral color measurement would not result in adequate performance for industrial applications.

3. Summary

The dependency of measurement performance on adequate color calibration with multi-spectral image acquisition systems was evaluated. *Adequate* means that color calibration is to be performed application-specific. For instance, if textile substrates are considered, color calibration has to be performed with a textile substrate color calibration chart in order to achieve high measurement performance. Using for instance paper substrate, color calibration has shown to decrease performance considerably. It is therefore generally recommended to use multi-spectral imaging with application-specific color calibration.

The reason behind the drop in performance is related to intrinsic spectral properties of the measurement substrates. Even though two objects from different material might appear similar in color as humans perceive it, their spectral properties might differ.

It is not trivial to predict the drop in measurement performance if non-application-specific color calibration is used. In cases where application-specific color calibration is not feasible for technical reasons, a case-by-case study has to be performed to evaluate the measurement performance that can be achieved.

References

[1] Chromasens GmbH – truePIXA: https://www.chromasens.de/en/product/multi-spectral-camera-truepixa-compact-12-channel-130dpi

[2] Konica Minolta - FD7: https://www.konicaminolta.eu/en/measuring-instruments/products/graphic-arts/fd-7/introduction.html

[3] CIE, “Improvement to industrial colour-difference evaluation,” tech. rep., CIE Publication No. 142-2001, 2001.