

Investigating the Possibility of Using Fewer Training Samples -- In the Color Prediction Model based on CIEXYZ using an Effective Coverage Map

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Abstract

The goal of the present work is to reduce the number of the training samples used in our color prediction model based on CIEXYZ using an Effective Coverage Map while keeping satisfying prediction. A general approach is proposed in this paper to choose the best reference combination for the training samples. The approach is based on the dot gain behavior of each primary ink, which is characterized by three curves using CIEXYZ tri-stimulus values. The proposed approach is built in our model to predict the color values for the color prints using two different devices, i.e. a laser printer and an inkjet printer. For the laser printer the number of the training samples is reduced from 125 to 64 while still giving quite good result. The approach also shows that for the test laser printer it is possible to further cut this number to 53 with a satisfying result. For the inkjet printer the number of training samples for our model is reduced from 125 to 79 or 64, both giving satisfying results.

Introduction

The color prediction model investigated in this paper is using an effective coverage map based on CIEXYZ values to predict the values of the resulting color in halftone print. The most famous and almost the simplest prediction model of halftone prints is the Murray–Davies (MD) model¹ in Equation 1, which describes the relationship between the reflectance spectrum of a color patch and the reflectance spectra of the involved full-tone ink and the white paper.

$$R(\lambda) = aR_i(\lambda) + (1-a)R_p(\lambda) \quad (1)$$

where $R(\lambda)$ is the predicted spectral reflectance and a is the fractional area of the ink. $R_i(\lambda)$ is the spectral reflectance of the printed ink at full tone and $R_p(\lambda)$ is the spectral reflectance of the substrate, i.e. paper. Because of the linear relationship between CIEXYZ values and the spectral reflectance², Equation 1 can be extended to Equation 2 based on CIEXYZ values, which is called Neugebauer's equations³.

$$\begin{bmatrix} X_{ave} \\ Y_{ave} \\ Z_{ave} \end{bmatrix} = a_i \begin{bmatrix} X_i \\ Y_i \\ Z_i \end{bmatrix} + (1-a_i) \begin{bmatrix} X_p \\ Y_p \\ Z_p \end{bmatrix} \quad (2)$$

where $(X_{ave}, Y_{ave}, Z_{ave})$ denote the average color of the patch, (X_i, Y_i, Z_i) denote the CIEXYZ values of the full-tone ink (Cyan, Magenta, Yellow), and (X_p, Y_p, Z_p) denote the CIEXYZ values of the paper. a_i is the fractional area covered by the ink and $1-a_i$ is the fractional area of unprinted paper.

Take the patches with single cyan for example; we can deduce the effective coverage of cyan by Equation 3, which is driven from Equation 2 by replacing $(X_{ave}, Y_{ave}, Z_{ave})$ with $(X_{mea}, Y_{mea}, Z_{mea})$, i.e. the measured CIEXYZ values of the cyan patch.

$$\begin{aligned} c_{eff}^X &= \frac{X_{C_{mea}} - X_p}{X_c - X_p} = dgc^X + c_{ref} \\ c_{eff}^Y &= \frac{Y_{C_{mea}} - Y_p}{Y_c - Y_p} = dgc^Y + c_{ref} \\ c_{eff}^Z &= \frac{Z_{C_{mea}} - Z_p}{Z_c - Z_p} = dgc^Z + c_{ref} \end{aligned} \quad (3)$$

where c_{eff}^X , c_{eff}^Y and c_{eff}^Z are the effective coverage of cyan corresponding to the reference coverage value c_{ref} and based on CIEX, Y and Z, respectively. (X_p, Y_p, Z_p) are the CIEXYZ tri-stimulus values of paper while (X_c, Y_c, Z_c) are the CIEXYZ tri-stimulus values of full tone cyan. The measured CIEXYZ values of a halftone cyan patch are $X_{C_{mea}}$, $Y_{C_{mea}}$ and $Z_{C_{mea}}$. dgc^X , dgc^Y and dgc^Z are the characterized dot gain of cyan corresponding to the reference coverage value c_{ref} .

If the cyan ink and the paper are both ideal then it would only be possible to find the effective dot coverage for cyan by using the reflectance spectra in longer wavelength, which corresponds to CIEX values⁴. The reason is that part of Equation 3 that relates to CIEY and CIEZ values are meaningless since $Y_c - Y_p$ and $Z_c - Z_p$ are almost zero for ideal cyan and paper. However the inks and paper are far from ideal, especially the inks⁵. By applying Equation 3 for a group of AM halftoned cyan patches with their reference percent coverage c_{ref} increasing from 0 to 100% printed by a laser printer, we obtain three characterization curves⁶ for cyan. Figure 1 illustrates the relationship between dgc^X , dgc^Y , dgc^Z and c_{ref} in Equation 3 for cyan and based on CIE X, Y, Z, respectively.

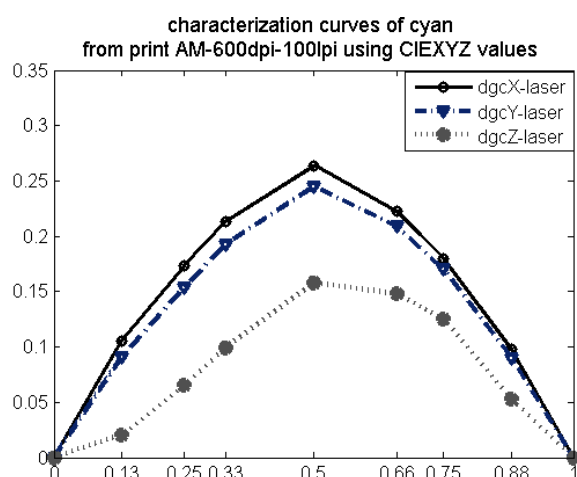


Figure 1. Characterization curves of cyan based on CIEXYZ printed by a laser printer (AM600dpi_100lpi).

Figure 1 clearly shows that the characterization curves of cyan using CIE X, CIE Y, and CIE Z differ from each other. The similar situation occurs for magenta and yellow. Therefore, it is

not completely correct to define only one characterization curve for each ink to be used in Neugebauer's equations when calculating the resulting color values⁶. It should also be noticed that, in our measurement of CIEXYZ values, there is actually optical dot gain included in the data. Hence the calculated three effective coverage values for a certain amount of ink include both the physical and optical dot gain⁷. Therefore, an advantageous proposal for color prediction is to use all the three different characterization curves based on CIEXYZ for each ink instead of a single curve⁴.

The usage of three different characterization curves based on CIEXYZ values differentiates our basic model from most of the other dot gain related models which use single dot gain curve for each primary ink. Our model does not either employ the n -factor⁸ which is used to deduce the optical dot gain in Yule-Nielsen equation based models.

According to the experiments, the dot gain of a certain amount of primary ink changes without obeying any observable rule when ink superposition happens⁹. For example the three characterization curves for cyan are no longer the same as those shown in Figure 1 if cyan is printed together with magenta or yellow or both. To improve our basic model presented in Ref.4, an effective coverage map is created in a simple way using several training patches, which is thoroughly described in Ref.6.

The map is put in a coordinate system whose three axes refer to the reference ink coverage of the three primary inks. The points in the map correspond to the chosen training patches; they are filled with the effective coverage values for each primary ink according to the reference coverage values of the involved inks. In Ref.6, we chose [0, 25%, 50%, 75%, 100%] as the reference coverage values for each ink to create the training patches. That means five training patches for each primary ink and totally 125 different combinations of the primary inks. How to build this map is introduced in Ref.6. As soon as this map is created, given any ink combination, we just carry out cubic interpolation over the map to get three effective coverage values based on X, Y and Z for each involved primary ink.

After the three effective ink coverage values of each involved primary ink are obtained, Demichel's equations¹⁰ are used to get the fractional coverage over the patch for each primary and secondary color. Equation 4 shows the fractional coverage for pure cyan, magenta, blue and paper based on CIEXYZ when there are only cyan and magenta involved.

$$\begin{aligned}
 c^X &= c_{eff}^X \cdot (1 - m_{eff}^X); & m^X &= m_{eff}^X \cdot (1 - c_{eff}^X); \\
 c^Y &= c_{eff}^Y \cdot (1 - m_{eff}^Y); & m^Y &= m_{eff}^Y \cdot (1 - c_{eff}^Y); \\
 c^Z &= c_{eff}^Z \cdot (1 - m_{eff}^Z); & m^Z &= m_{eff}^Z \cdot (1 - c_{eff}^Z); \\
 b^X &= c_{eff}^X \cdot m_{eff}^X; & p^X &= (1 - c_{eff}^X) \cdot (1 - m_{eff}^X); \\
 b^Y &= c_{eff}^Y \cdot m_{eff}^Y; & p^Y &= (1 - c_{eff}^Y) \cdot (1 - m_{eff}^Y); \\
 b^Z &= c_{eff}^Z \cdot m_{eff}^Z; & p^Z &= (1 - c_{eff}^Z) \cdot (1 - m_{eff}^Z);
 \end{aligned} \tag{4}$$

The tri-stimulus values (X_{cal} , Y_{cal} , Z_{cal}) of the print is then calculated using Equation 5 (take cyan accompanied with magenta as example).

X_c , Y_c and Z_c are the CIEXYZ values of full tone cyan, the indices c , m , b , p refer to cyan, magenta, blue and paper respectively. The superscripts X, Y, Z imply that the values are based on CIEX, Y, Z, respectively.

$$\begin{aligned}
 X_{cal} &= c^X \cdot X_c + m^X \cdot X_m + b^X \cdot X_b + p^X \cdot X_p \\
 Y_{cal} &= c^Y \cdot Y_c + m^Y \cdot Y_m + b^Y \cdot Y_b + p^Y \cdot Y_p \\
 Z_{cal} &= c^Z \cdot Z_c + m^Z \cdot Z_m + b^Z \cdot Z_b + p^Z \cdot Z_p
 \end{aligned} \tag{5}$$

In Ref.6 the performance of our model was shown to be quite well and better than that of the improved Yule-Nielsen modified spectral Neugebauer model¹¹ when using a laser printer (Xerox, Phaser 6180) and uncoated A4 office paper. The halftoning methods were Amplitude Modulated (AM) and first generation Frequency Modulated (FM1st)¹². The print resolution and screen frequency were 600dpi (100lpi) and 300dpi (100lpi) for AM and 300dpi for FM1st.

Although our color prediction model performs well, it used totally 125 training patches. The main goal of this paper is to find a general approach to reduce the number of the training patches while keeping the good performance of our color prediction model.

The Characterization Curves of Single Inks based on CIEXYZ

In this paper we use two print devices: the first one is a laser printer (Xerox, Phaser 6180) with uncoated A4 office paper, i.e. the same one used in Ref.6; the second one is an inkjet printer (Epson Stylus PRO 4000) with photo quality ink jet paper. We focus on the prints using Amplitude Modulated (AM) halftoning and use 600dpi and 100lpi to be the print resolution and screen frequency respectively.

To investigate the model we printed 729 patches whose reference coverage of each primary ink is picked from [0, 0.13, 0.25, 0.33, 0.5, 0.66, 0.75, 0.88, 1]. The reason we chose these values is that the series [0, 0.25, 0.5, 0.75, 1], which we chose to create the training patches in our previous work, is the medial series with 5 elements varying from 0 to 1, and the series [0, 0.33, 0.66, 1] is the medial series with 4 elements growing from 0 to 1. The value 0.13 is the middle value between 0 and 0.25. The value 0.88 is also the middle value between 0.75 and 1. Hence the chosen 9 values are good candidates to potentially be used as the reference coverage of the training patches. To evaluate the accuracy of the model, 519 test patches with random reference coverage values are printed.

Before we start, we review the performance of our model using 125 training patches whose reference coverage values are [0, 0.25, 0.5, 0.75, 1]. The improved Yule-Nielsen modified spectral Neugebauer model that was introduced in Ref.11 is also used to help us to evaluate the performance of the approaches in this paper. In that model the effective coverage values of each involved ink are found by weighting the contributions from different reproduction curves according to the weights of the contributing superposition conditions. It is operated based on spectrum reflectance data.

The E_{94} Color Differences for the 519 test patches achieved by the two models are listed in the first two columns in Table 1. The n -factor used for the improved Yule-Nielsen modified spectral Neugebauer model is optimized using 44 samples. Which 44 samples and how they are chosen are introduced in Ref.11.

The training patches are used to create a 3-D effective map in our model; therefore reducing the number of the training samples is actually the same as cutting down the number of the values on each reference coverage coordinate axis in the map. The first step worth trying is to use [0, 0.33, 0.66, 1] instead of [0, 0.25, 0.5, 0.75, 1] as the reference coverage

values for the training patches. That means to cut the number of training patches down to 64 from 125. We executed this

proposal and present the results of the E_{94} Color Difference in the last column of Table 1.

Table 1. The ΔE_{94} Color Difference between measured and calculated values for 519 random AM600dpi-100lpi test patches.

Print Devices	Models	Effective coverage Mapping				Yule-Nielsen modified spectral Neugebauer				Effective coverage Mapping			
		Mean	Max	>3	>4	Mean	Max	>3	>4	Mean	Max	>3	>4
Laser printer A4 copy paper	Training coverage [0, 0.25, 0.5, 0.75, 1]					n= 2.1				Training coverage [0, 0.33, 0.66, 1]			
		Mean	Max	>3	>4	Mean	Max	>3	>4	Mean	Max	>3	>4
		1.41	4.55	25	7	1.59	6.53	40	12	1.59	5.43	36	8
Inkjet printer Photo quality inkjet paper	Training coverage [0, 0.25, 0.5, 0.75, 1]					n= 2.9				Training coverage [0, 0.33, 0.66, 1]			
		Mean	Max	>3	>4	Mean	Max	>3	>4	Mean	Max	>3	>4
		1.49	4.25	17	2	1.80	5.73	52	12	1.91	5.35	65	13

The results show that for the test patches printed by laser printer on A4 copy paper, using [0, 0.33, 0.66, 1] in our model, the E_{94} Color Difference between the predicted and the measured data is getting worse compared with using [0, 0.25, 0.5, 0.75, 1]. However, our model still gives better results than the improved Yule-Nielsen modified spectral Neugebauer model. For the printed colors using inkjet printer and photo quality ink jet paper, using [0, 0.33, 0.66, 1], the E_{94} Color Difference gets worse than both our model using [0, 0.25, 0.5, 0.75, 1] and the improved Yule-Nielsen modified spectral Neugebauer model.

In order to characterize the prints and investigate the possibility of reducing the number of the training samples, we have printed 9 patches of single ink with the coverage equal to [0, 0.13, 0.25, 0.33, 0.5, 0.66, 0.75, 0.88, 1] for each primary

ink. We then measured CIEXYZ values of these patches to find out the characterization curves of each primary ink. Figure 2 presents the characterization curves for cyan, magenta and yellow respectively and for the two print devices.

In Figure 2, the characterization curves of a certain kind of ink for two different print devices are presented in one window. It shows that the effective coverage of cyan and yellow for the test laser printer are bigger than that for the test inkjet printer. The effective coverage of halftoned magenta for the two print devices are numerically close to each other. It can also be noticed that the characterization curves of the three inks for inkjet printer (photo quality ink jet paper) are not as symmetrical around 0.5 as the curves for laser printer (normal A4 copy paper).

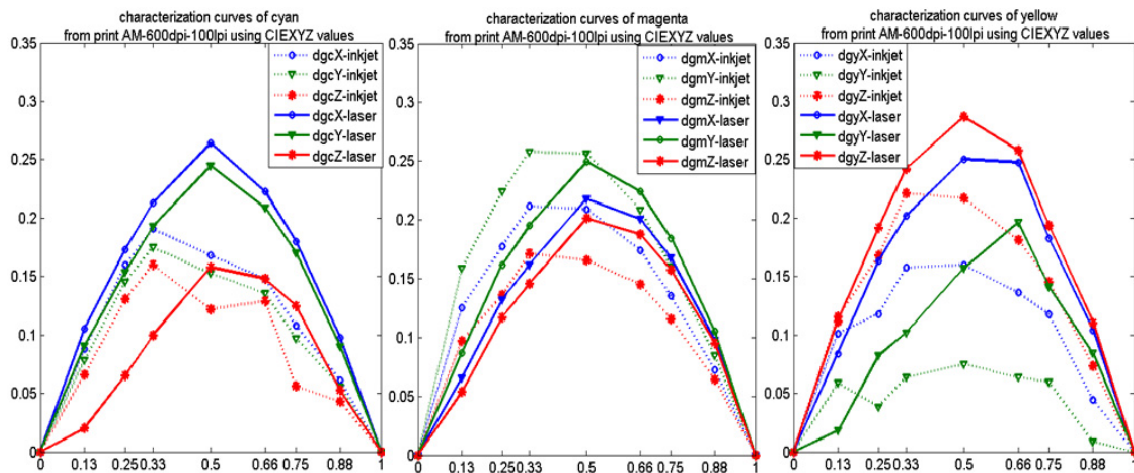


Figure 2. Characterization curves of (a) cyan; (b) magenta; (c) yellow, (AM600dpi_100lpi) based on CIEXYZ, using laser printer (solid lines) and inkjet printer (dashed lines).

For the inkjet printer, the reference coverage which produce the bigger dot gain are shifted to the left compared with that for the laser printer. For the inkjet printer the series [0, 0.25, 0.66, 1] might be more suitable to be chosen as the reference coverage values for the training patches than [0, 0.33, 0.66, 1]. Therefore in some cases the series of reference coverage values uniformly located between 0 and 1 might not

be the best choice for a certain primary ink. However, this reasoning might not be valid for the case of using 5 elements for the reference coverage series. In that case the minimum optional interval between any 2 neighboring elements of the 5 is around 0.13 which is not very big. Since we use 3-D cubic interpolation, if the distance between two neighboring samples is small then in some cases it might cause the interpolation

curve to be oscillating, which can result in false effective coverage. Therefore, it is recommended to apply the uniform series of values, i.e. [0, 0.25, 0.5, 0.75, 1], to define the reference coverage combinations of training samples in the case of using 5 elements.

In the next section we propose a general approach to reduce the number of training patches and find the best combination of coverage for each primary ink.

Reducing the Number of the Training Patches

In order to reduce the number of the training patches while keeping the prediction results satisfying, we propose the following approach. The approach will choose the best reference coverage values for cyan, magenta and yellow to create the training samples.

1) We print a group of patches with single halftone cyan, magenta and yellow, each with the reference coverage [0, 0.13, 0.25, 0.33, 0.5, 0.66, 0.75, 0.88, 1].

2) We set the preferred number of reference coverage values, n , for each ink. For example in this paper we want to use not more than 4 values to create $4 \times 4 \times 4 = 64$ or even less than 64 color patches as training samples.

The possible series of values from [0, 0.13, 0.25, 0.33, 0.5, 0.66, 0.75, 0.88, 1] are picked obeying two rules. Firstly, the value 0, which means white paper, and the value 1, which means full-tone ink, should always be chosen. Secondly, in order to avoid the training coverage to be too close to each other or too far away from each other the distance between two neighboring values should be between $\frac{1}{2} \times \frac{1}{n-1}$ and $\frac{3}{2} \times \frac{1}{n-1}$.

Where $\frac{1}{n-1}$ is the average distance between two neighbors if

the number of the elements is limited to be n . The possible series with 4 or 3 elements for each ink are shown in Table 2. They are automatically chosen in our model.

3) For each ink we use the possible series to predict the color of the other patches. For example, in series 1 we use the 4 coverage [0, 0.25, 0.66, 1] as the reference for the training patches and predict the color of the rest of the patches, i.e. those with the reference coverage [0.13, 0.33, 0.5, 0.75, 0.88]. This is done by firstly characterizing three curves for each primary ink based on CIEXYZ tri-stimulus values using the 4 patches [0, 0.25, 0.66, 1]. Then we find out the three effective coverage values corresponding to different amount of the ink, in this case [0.13, 0.33, 0.5, 0.75, 0.88], by interpolating along the three characterization curves of that ink. Observe that this is done for cyan, magenta and yellow separately. Then the same procedure is repeated for the other possible series, i.e. series No.2 to 6.

Since the test patches are single ink, the average color of the test patches could be calculated by Equation 2 based on CIEXYZ values. Table 2 shows the average E_{94} Color Differences ($m E_{94}$) for different possible series and different primary inks. We then choose the best reference coverage values for the possible series according to $m E_{94}$. Take cyan printed by laser printer as an example. The results in Table 2 show that since [0, 0.33, 0.75, 1] gives the smallest $m E_{94}$ it might be the most suitable series for cyan.

The similar procedure is carried out for magenta and yellow patches printed by the two devices. The average E_{94} Color Differences ($m E_{94}$) for different inks, printers and possible series are presented in Table 2. They are used to find out the suitable series of reference coverage values with 4 or 3 elements for each situation.

Table 2. The possible series of reference coverage values with less than 5 elements.

The average ΔE_{94} Color Differences obtained by carrying the procedure over different inks and printers.

Series No.	Number of elements	Possible Reference Coverage Values	Laser printer + A4 copy paper			Inkjet printer +Photo quality ink jet paper		
			$m\Delta E_{94}$			$m\Delta E_{94}$		
			Cyan	Magenta	Yellow	Cyan	Magenta	Yellow
1	4	[0, 0.25, 0.66, 1]	0.70	0.60	0.81	0.38	0.40	0.41
2	4	[0, 0.33, 0.66, 1]	0.61	0.61	0.76	0.49	0.49	0.52
3	4	[0, 0.33, 0.75, 1]	0.59	0.52	0.77	0.50	0.50	0.52
4	3	[0, 0.33, 1]	0.84	1.34	0.63	1.27	3.66	1.25
5	3	[0, 0.5, 1]	1.08	0.88	0.77	0.74	2.61	0.76
6	3	[0, 0.66, 1]	0.84	0.83	0.76	0.78	2.61	0.84

Results and Discussion

For simplicity, $refc$, $refm$, $refy$ are used to denote the chosen series of reference coverage values for cyan, magenta and yellow, respectively. These values are listed in Table 3. The training patches then will be used to build the effective coverage map which is used to predict the color of the 519 random test patches. The E_{94} Color Difference between the predicted and the measured data of the random test patches are presented in Table 3.

Table 2 shows that the best choice for $refc$, $refm$, $refy$ for laser printer are [0, 0.33, 0.75, 1], [0, 0.33, 0.75, 1] and [0, 0.33, 1] respectively, also see column 1 in Table 3. It means that $4 \times 4 \times 3 = 48$ patches are used as training samples for our model. Adding the prints with single inks, the total number of training samples is $48 + [(9-4) + (9-4) + (9-3)] = 64$, which is the same as in previously attempted to use $refc=refm=refy=[0, 0.33, 0.66, 1]$, see Table 1. However the resulting E_{94} Color Difference for

$refc=[0, 0.33, 0.75, 1]$, $refm=[0, 0.33, 0.75, 1]$ and $refy=[0, 0.33, 1]$ are smaller than the corresponding results in Table 1 using $refc=refm=refy=[0, 0.33, 0.66, 1]$. The result is also better than those for the improved Yule-Nielsen modified spectral Neugebauer model.

The chosen reference coverage for inkjet printer are $refc=refm=refy=[0, 0.25, 0.66, 1]$, see Table 2, and the resulted E_{94} Color Differences are less than that using $refc=refm=refy=[0, 0.33, 0.66, 1]$, see Table 1 and 3. It is also better than the results for the improved Yule-Nielsen modified spectral Neugebauer model. The total number of the training patches used in this case is $64 + [(9-4) + (9-4) + (9-4)] = 79$.

We can now conclude that we need 64 and 79 training samples for the test laser and inkjet printer respectively, if we want to achieve the best result with the number of coverage in $refc$, $refm$ and $refy$ being less than five.

Table 3. The ΔE_{94} Color Difference between measurement and calculated values for 519 Random AM600dpi-100lpi Test patches

Devices	Models	Effective coverage Mapping The best option				Effective coverage Mapping Example of other Option				Effective coverage Mapping Example of other Option			
		Mean	Max	>3	>4	Mean	Max	>3	>4	Mean	Max	>3	>4
Laser printer A4 copy paper		<i>refc</i> = [0, 0.33, 0.75, 1] <i>refm</i> = [0, 0.33, 0.75, 1] <i>refy</i> = [0, 0.33, 1]				<i>refc</i> = [0, 0.33, 0.75, 1] <i>refm</i> = [0, 0.5, 1] <i>refy</i> = [0, 0.33, 1]				<i>refc</i> = [0, 0.33, 1] <i>refm</i> = [0, 0.33, 0.75, 1] <i>refy</i> = [0, 0.33, 1]			
		1.51	5.33	26	8	1.81	5.65	58	10	1.67	6.04	43	13
Inkjet printer Photo quality inkjet paper		<i>refc</i> = [0, 0.25, 0.66, 1] <i>refm</i> = [0, 0.25, 0.66, 1] <i>refy</i> = [0, 0.25, 0.66, 1]				<i>refc</i> = [0, 0.25, 0.66, 1] <i>refm</i> = [0, 0.25, 0.66, 1] <i>refy</i> = [0, 0.5, 1]				<i>refc</i> = [0, 0.25, 0.66, 1] <i>refm</i> = [0, 0.66, 1] <i>refy</i> = [0, 0.25, 0.66, 1]			
		1.72	4.94	43	6	1.80	5.73	52	12	2.77	10.26	198	95

The proposed general approach could also help to further reduce the number of the training patches. For the laser printer we have already achieved good results with cutting the number of training samples to 4x4x3 (4 for cyan, 4 for magenta, and 3 for yellow). Now we want to examine the possibility to reduce the number of the training patches to 3x4x3 or 4x3x3. The first question is which one of these two cases is more appropriate, i.e. using fewer elements for cyan or magenta. In Table 2 we can see that the best $m E_{94}$ for cyan using 4 and 3 coverage is 0.59 and 0.84, respectively. It means that $m E_{94}$ is worsening by 0.84-0.59=0.25. The same values for magenta are 0.52 and 0.83, which differ by 0.31. As can be noticed both of these differences are small and therefore we can expect that the prediction results cannot be affected much if we go from 4 to 3 elements for either cyan or magenta. Since the difference for cyan is slightly smaller, then the case 3x4x3 is preferred to the other one. The results in Table 3 (column 2 and 3) also verify that going from 4x4x3 to either 4x3x3 or 3x4x3 doesn't significantly affect the prediction results for the test laser printer. It also shows that the case 3x4x3 is slightly better than 4x3x3, as we expected. The number of the training patches for these two cases are 36+[(9-3)+(9-4)+(9-3)]=53. For the inkjet printer we use the same strategy to reduce the number of the training patches by going from 4x4x4 to 3x4x4, 4x3x4 or 4x4x3 training patches. The differences in $m E_{94}$ going from 4 to 3 for these cases are 0.74 - 0.38=0.36, 2.61 - 0.4=2.21 and 0.76 - 0.41=0.35 for cyan, magenta and yellow respectively. These values indicate that 4x3x4 is not a good choice at all and Table 3 (column 3) confirms that. The other two choices give very close $m E_{94}$ difference but we choose 4 x 4 x 3 and show the result in Table 3 (column 2). The number of the training patches now is reduced to 48+[(9-4)+(9-4)+(9-3)]=64.

In this paper we proposed a general approach to reduce the number of the training samples in our model, i.e. Color Prediction Model Based on CIEXYZ using an effective coverage map. For the laser printer this number was reduced from 125 to 64 while still giving quite good results. We also showed that it is possible to further cut this number to 53 with a satisfying result. For the inkjet printer we reduced this number from 125 to 79 or 64, both giving satisfying results.

The proposed approach can be used to further reduce the number of the training patches but for our test printers we reached the limit of this number for a satisfying prediction, which is 53 and 64 for the laser and inkjet printer, respectively. We suppose that our model with the proposed approach is potentially useful for building an Automated CtP (Computer to Plate) Calibration System in printing workflow.

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