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Investigation of the effects of different ink density values on color gamut in offset printing

ABSTRACT

A standard color gamut can be obtained with CMYK samples that are printed with an offset printing system according to the ISO 12647-2:2013. It is possible to enhance or widen the color gamut during the printing process by interfering with the density and dot gain characteristics. Printing with a wider color gamut provides a more vivid area and more depth in color. In this study, print trials were conducted at first with standard values (density, dot gain and such). Then another trial was conducted by changing the density values respectively during the trial. Ink density values for all colors were decreased from the standard value as -0.15D, -0.30D and then increased as +0.15D, +0.30D. Color gamuts of the trials were calculated and compared at the end. It is found that ink density values directly affect color gamut in offset printing. It is also found that the color gamut decreases equally when ink density values decrease and vice versa. However, some printing problems occurred with high density values even though it gave an expanded color.

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offset printing, dot gain, solid density, color gamut

Introduction

One of the most important reasons of increased print quality is the use of inks with a high coloring feature (Leach & Pierce, 1993). The film thickness of the ink should be below 2µm during printing (Dalton et al, 2002). The critical point is the direct effect of ink film thickness on print quality and color gamut. Ink absorption of paper and drying are the other important factors (Zjakić, Bates & Milković, 2011). It is also very important to have suitable solid ink density values for the used paper surface to achieve the desired print quality and color gamut. When the optimum amount of ink that is transferred onto the paper is set, the print quality as well as the color gamut will increase.

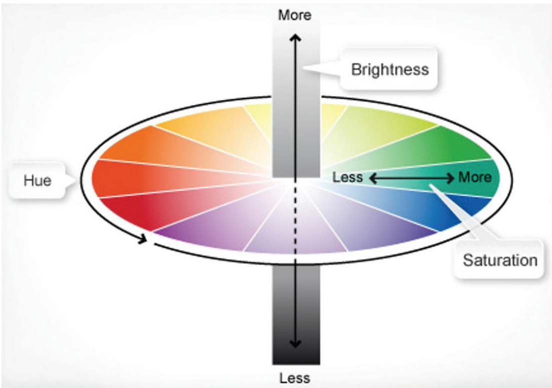
Color Systems and Color Gamut

The need of developing an international standard that everyone can understand increased as the importance of color increased in the industry. At the beginning of the 20th century, a painter named A.H. Munsell defined the color schemes. The CIE that was established in 1930 explains the base color structure with three coordinates.

There are three elements of color: hue, saturation and brightness Offset printing is a commonly used printing technique where the inked image is transferred from a printing plate to a rubber blanket, then to the printing surface (Ozcan & Oktav, 2011) and at the same time offset printing is a preferred system in terms of keeping pace with the advancing technology and print quality. Ink density is the first factor that affects the quality. The density impacts color gamut directly. High print density could also cause different print defects (drying and such). Therefore, optimum print density should be obtained in order to get the widest color gamut (Sahinbaskan, 2002).

Hue: The ‘attribute of visual sensation according to which an area appears to be similar to one, or to proportions of two, of the perceived colors red, yellow, green, and blue.' Looking at an orange, for example, we can see that its color is similar to both red and yellow and we could express its hue as some percentage of each of the two (e.g. 60% red and 40% yellow) (Morovič, 2008).

Saturation: is a unique perceptual experience separate from chroma. Like chroma, saturation can be thought of as relative colorfulness. However, saturation is the colorfulness of a stimulus relative to its own brightness, while chroma is colorfulness relative to the brightness of a similarly illuminated area that appears white (Fairchild, 2013).



» **Figure 1:** *CIE color gamut*

Brightness: The attribute of a visual sensation according to which an area appears to exhibit more or less light.' Returning to the same orange, we can also express this attribute of its color appearance and we would judge it to be higher for parts of it that are directly lit and lower for parts that are in the shade (Morovič, 2008).

CIE color systems places a color to the color gamut with the values of these three components. The CIE has designed many color models over the years. Although these models differ in the process of technological developments, hue, saturation and brightness are the base components (Sahinbaskan, 2002).

CIE L*a*b*

The purpose of CIE is to form a system to enable clear and repeatable production for people who printable produce the color. Forming a universal color template is the target. The important parts of this template are defined as the standard observer and XYZ color gamut. However unbalanced structure of the XYZ color gamut has made it difficult to establish the standards (Sahinbaskan, 2002; Tritton 2004).

In 1976, with a view to approximating perceptual uniformity by emulating the nonlinear response of the human eye, the CIE recommended the CIE L*a*b* space (lightness, position between green and magenta and position between blue and yellow) (Rivas et al., 2011). It works with three basic signals just as in the human eye. These are light-dark, red-green, yellow-blue. CIE, CIE L*a*b* and CIE L*u*v* are established on the basis of this more uniform detection color system. The balanced L*a*b* color structure was built based on the fact that a color can't be green, red or another color at the same time. Simple values can be used to describe a color. L* represents the lightness, a* represents the red/green value, b* represents the yellow/blue value of the color in the CIE L*a*b* system (Tritton, 2004; Adams & Weisberg 2000).

L* value determines the brightness from 0 to 100, meaning how dark or light the color is.

a* positive values determine the redness from 0 to 100. a* negative values determine the greenness from 0 to 100.

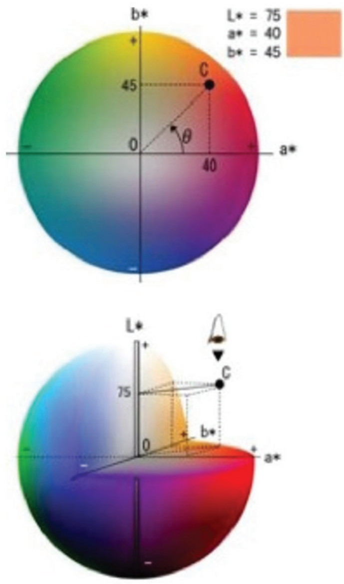
b* positive values determine the yellowness from 0 to 100. b* negative values determine the blueness from 0 to 100.

CIE L*a*b* is the most commonly used color gamut. Computers and software's used in desktop publishing are based on CIE L*a*b* system.

The following equation is used to obtain the L*a*b* values from the tristimulus values.

$$L^* = 116\,(Y/Y_n)^{1/3} - 16$$
$$a^* = 500[(X/X_n)^{1/3} - (Y/Y_n)^{1/3}]$$
$$b^* = 200[(Y/Y_n)^{1/3} - (Z/Z_n)^{1/3}]$$

X, Y, Z values are the tristumulus values of measured color; Xn, Yn, Zn are the tristimulus values of light (Sahinbaskan, 2002).



» **Figure 2:** *CIE L*a*b* color gamut model*

Materials and Methods

In this part of the study, the device and materials that were used for the experiment are summarized. First a test page was created, then print trials were made and finally measurements were conducted and evaluated. Print trials were made on glossy coated paper on a Heidelberg- Printmaster 35x50 cm printing machine. The printed papers were measured i1iO, and the profiles were created by using X-rite ProfileMaker. The color gamuts made by using the profiles and the differences between them were shown in the tables.

- Printing Machine: Heidelberg- Printmaster 35 x 50 cm
- Screen frequency: 70 lpc
- CtP: Fujifilm / Vx 6000
- Plate: Fujifilm, Brilla
- Paper: UPM 135 g/m^2 Glossy Paper
- Ink: DYO ink, Standard CMYK
- Density Measurements: GretagMachbeth Spectrophotomer, i1iO

» **Figure 3:** *i1iO Measurement device for test pages*

Results and discussion

Measured Print Values:

* In editing, ink solid densities-0.30D,-0.15D, +0.15D, +0.30D was planned to increase and decrease. However, some fluctuations occurred in these values.

Measured Solid Print Density Values printed on UPM 135 g/m^2 Glossy Paper;

Cyan: 1.49 D,
Magenta: 1.43 D,
Yellow: 1.41 D,
Black: 1.83 D

Table 1

ISO 12647-2:2013 standard CMYK and measured L*a*b* values

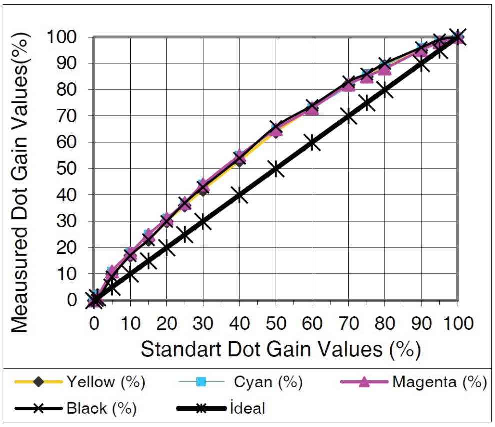
Color	L	a*	b*
Cyan	55	-37	-50
Magenta	48	74	-3
Yellow	89	-5	93
Black	16	0	0
Red	47	68	48
Green	50	-68	25
Blue	24	17	-46
White Paper	95	0	-2

Color	L	a*	b*
Cyan	58.4	-35.31	-50.12
Magenta	51.08	73.02	-5.41
Yellow	89.94	-4.89	93.41
Black	16.48	1.02	0.52
Red	49.12	66.03	48,57
Green	50.85	-64. 13	30.01
Blue	24.76	18.76	-45.07
White Paper	94.66	0.78	-4.16

Table 2

Measured CMYK printing dot gain values printed on UPM 135 g/m2 Glossy Paper

Original (%)	Yellow (%)	Cyan (%)	Magenta (%)	Black (%)
1	2	2	1	0
5	10	11	11	9
10	17	18	18	17
15	23	25	25	23
20	30	31	31	30
25	36	37	37	37
30	42	44	44	43
40	53	55	55	54
50	64	65	65	66
60	73	73	73	74
70	82	81	82	83
75	85	86	85	86
80	89	89	88	90
90	95	96	95	96
95	98	98	98	99
100	100	100	100	100
Density	1.41	1.49	1.43	1.83



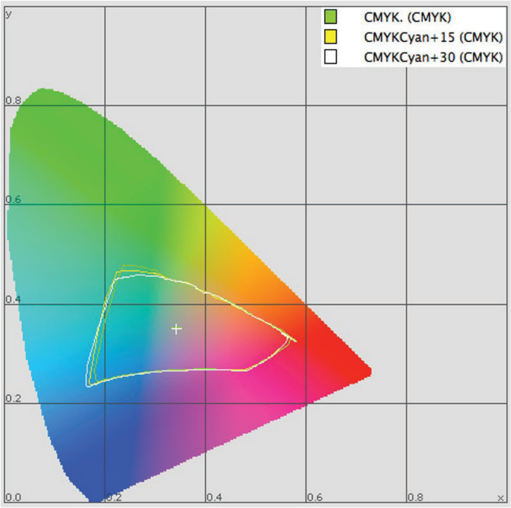
» **Figure 4:** *Measured CMYK printing dot gain curves printed on UPM 35 g/m^2 Glossy Paper*

For the first trial, cyan density values were increased while the other color values were kept same.
Cyan; 1.56 D, 1.69 D, 1.83 D, Other color density values are same.

Table 3

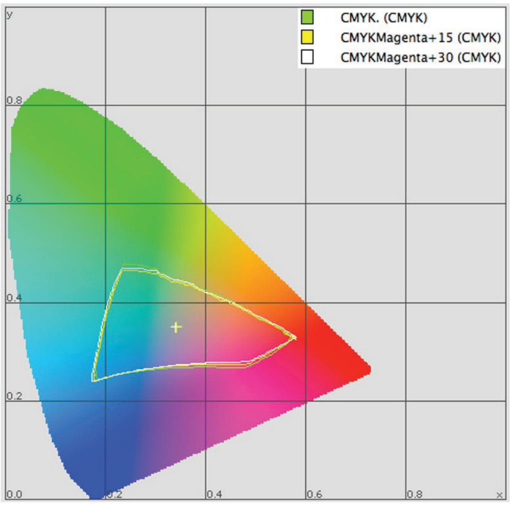
Measured CMYK printing ΔE values

Cyan (C)	Magenta (M)	Yellow (Y)	Black (K)
3.2	5.6	0.9	1.2



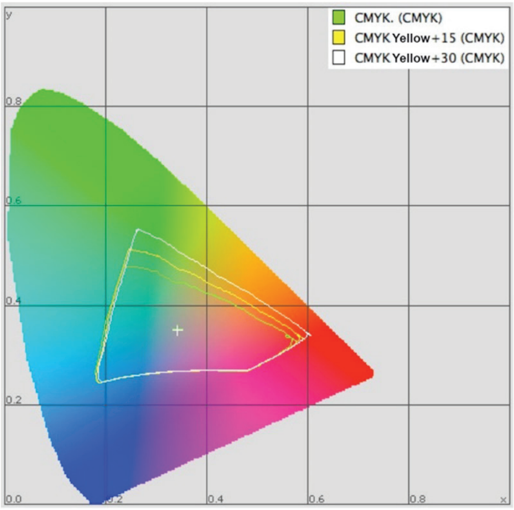
» **Figure 5:** *Cyan ink density values effect on the color gamut*

Figure 5 shows that the color gamut increased slightly in comparison with the ISO 12647-2:2013 when cyan density values were increased +0.15D and +0.30D while the other colors were kept the same.
For the second trial, magenta density values were increased while the other color values were kept the same.
Magenta; 1.48 D, 1.67 D, 1.81 D, other color density values are same.



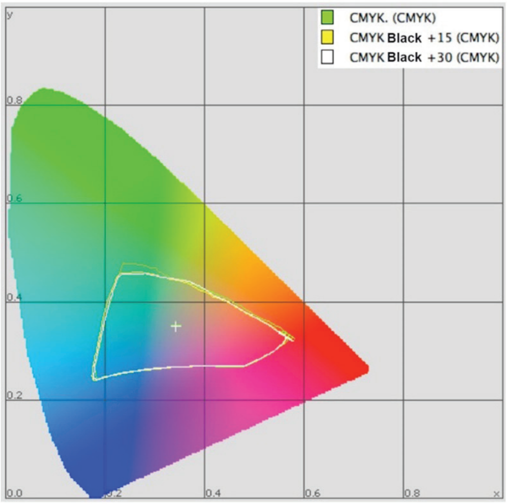
» **Figure 6:** *Magenta ink density values effect on the color gamut*

Figure 6 shows that the color gamut did not change in comparison with the ISO 12647-2:2013 when magenta density values were increased +0.15 D and +0.30 D while the other colors were kept the same.
For the third trial, yellow density values were increased while the other color values were kept the same. The dot values on the plate were decreased 20% compared to the standard values.
Yellow; 1.05 D, 1.19 D, 1.37 D, Other color density values are same.



» **Figure 7:** *Yellow ink density values effect on the color gamut*

Figure 7 shows that the color gamut was increased in the yellow region in comparison with the ISO 12647-2:2013 when magenta density values were increased +0.15D and +0.30D while the other colors were kept the same. It was observed that the changed dot values affected the result.
For the fourth trial, black density values were increased while the other color values were kept the same.
Black; 1.83 D, 2,08 D, 2.16 D, Other color density values are same.



» **Figure 8:** *Black ink density values effect on the color gamut*

Figure 8 shows that the color gamut did not change in comparison with the ISO 12647-2:2013 when magenta density values were increased +0.15D and +0.30D while the other colors were kept the same.

Density values of all colors were changed in certain proportions and color gamuts were compared to each other.

For the fifth trial, all color density values were increased first +0.15D and +0.30D, then decreased-0.15D and -0.30D compared to the ISO 12647-2.

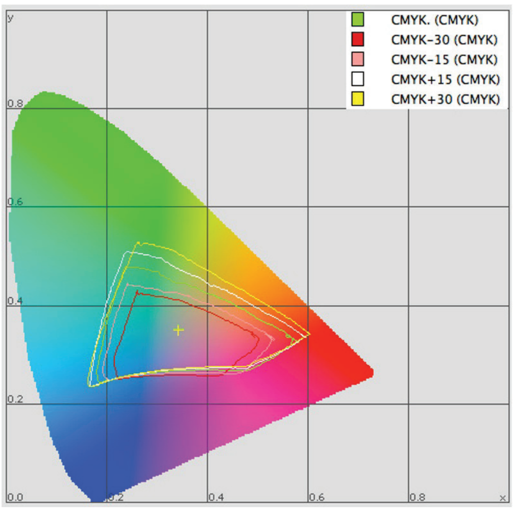
When increase and decrease measured CMYK density values

Cyan; 1.28 D, 1.41 D, 1.48 D, 1.67 D, 1.89 D

Magenta; 1.18 D, 1.31 D, 1.42 D, 1.61 D, 1.78 D

Yellow; 1.21 D, 1.32 D, 1.43 D, 1.58 D, 1.75 D

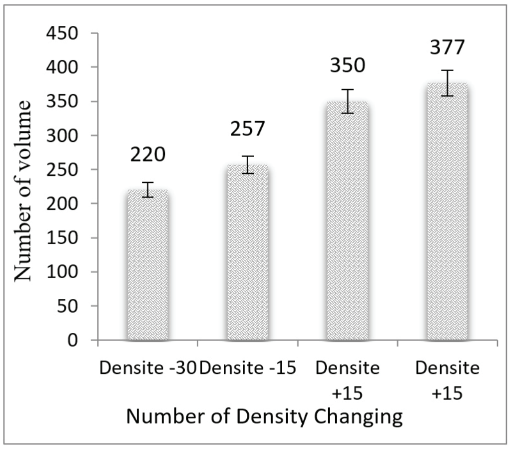
Black; 1.53 D, 1.68 D, 1.81 D, 1,98 D, 2.07 D



» **Figure 9:** *-0.30D and +0.30D density values effect on the color gamut*

Figure 9 shows the effect of the changed density values on the color gamut. The green color gamut represents the ISO 12647-2. The color gamut obtained with +0.15D and +0.30D CMYK density values is wider. The white gamut represents +0.15D density values; the yellow gamut represents +0.30D density values. The color gamut decreased when the density was decreased-0.15D and -30D. The pink gamut represents-0.15D the red gamut represents-0.30D density values.

When we increased the solid tone density from -30 D to +30 D, the color gamut was expanded.



» **Figure 10:** *ISO 12647-2 standard CMYK color gamut volume diagram*

Conclusions

It is found that ink density values directly affect color gamut in offset printing. It is also found that the color gamut decreases equally when ink density values decrease and vice versa.
However, some printing problems occurred with high density values even though it gave an expanded color gamut. The problems were delay in ink setting, set-off and blocking. Even though the color gamut is important, it is more essential to use optimum ink density values to have a trouble-free printing process.

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