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A Hybrid Model Approach for Achieving the Highest Level of Matching Between the "Print and Original" in the Sheet-Fed Offset Process

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Abstract:

This study was designed to explore an optimized hybrid system through dual measurement approach of contrast measurement method and CIE L*a*b* measurement method to arrive a logical interface for achieving the highest matching between the print and original in sheet fed offset printing process. The work was started with the detailed study of contrast measurement, CIE L*a*b* measurement method, visual and computational intelligence based assessment and control. The master was designed in such a way that value of density and other values can be measured easily in effective way. X-Rite eXact instrument is used for capturing the readings, the 10 standard observers were selected initially by manual method and finally by using on line Fransworth-Munsell 100 Hue Colour Vision Test and visual assessments and judgement were done on X-Rite's Macbeth Lighting Booth and their visual assessments are recorded, analyzed and represented. All the parameters like Paper, Ink, Measuring Conditions and Measuring Instruments etc. were maintained in compliance with ISO specifications. After the analysis of data, the study reached to the following main conclusion i.e. It is observed that almost in all the cases, preference of the Standard Observers are for Delta E Value leading to the higher contrast value instead of Minimum Delta E with less contrast value. Therefore the dual approach of "Hybrid System" will help us to arrive at the most convincing, measurable and perceptually acceptable print result which will be the highest (closest) match to the original by clubbing the best of "CIE Lab, Contrast Method and Standard Observers Visual Perception" as there are positives and negatives in all these three when one approaches individually. The objective of this paper was to develop a dual measurement approach of CIE Lab & Contrast to arrive at a logical inference for the highest level of matching between the original and print in the sheet fed offset printing.

Key words:

Hue, U.V. light, Print Contrast, CIE, LAB Values, Delta E, Standard Observer, HMA.

1 Introduction

Almost all living beings experience Colour and feel enjoyment and happiness. The soul of any printed material is Colour, particularly when it is multicolour. Even black and white coloured prints leave impressions. The colour sensation is achieved when electromagnetic waves between the limits of approximately 380 and 780 nanometers are perceived by eye. These waves are named as 'light waves'.(www.primiercolorscan.com), (Schildgen, Thomas E., 1998, pp.1-3) Eyes perceive colours though a mechanism.

There are different methods and models available for explanation, computation and measurement of colour and colour values, but Colour is a phenomenon, a perception, and perceptions exist only in mind. That is why in most imaging applications, a human observer, and not a measuring instrument, is the ultimate judge of colour quality. Colour appearance is influenced by various psychophysical and psychological signal processing effects (Sharma, A., 2003, p.71).

Therefore to explore an optimized hybrid system through dual measurement approach of contrast measurement method and CIE L*a*b* measurement method to arrive a logical interface for achieving the highest matching between the print and original in sheet fed offset printing process. The work was started with the detailed study of contrast measurement, CIE L*a*b* measurement method, visual inspection, virtual sensor (Lundstrom. J, et al, 2013, p.1429) and computational intelligence (Verikas.A, et al, 2011, p. 13443) based assessment and control. The master was designed in such a way that value of density and other values can be measured easily in effective way.

2 Contrast and colour measurement

Densitometric and colourimetric processes and related instruments are used for colour measurements on the printed sheet. Densitometric techniques are nothing but the measurement of ink film thickness which is printed. Optical density measurement is a common process and for this, dependable measuring instruments are available which can determine the parameters like dot gain, print contrast, trapping along with density in Black and White as well as in coloured printing (Kipphan, H., 2001, p.100).

If we have the measured values of the ink density in the solid DS and the ink density in the halftone screen D80 than we can calculate the relative printing contrast and for the same it is always preferred to measure the D80 value around the three-quarter tone and average of three readings; for instance 80% from the colour control bar (Kippen, H., 2001, p.103) as per formulae given below:

$$K = (DS\text{-}D80 \,/\, DS) \times 100\% \qquad (1)$$

3 CIE L*a*b* colour system

The L*a*b* colour space is also referred to as CIELAB and presently it is one of the most popular colour spaces for measuring object colour and is widely used in all fields. It is one of the uniform colour spaces defined by CIE in 1976 in order to reduce one of the major problems of the original Yxy colour space in which the equal distances on the x, y chromaticity diagram do not correspond to equal perceived colour differences. (Cf. Konica Minolta Brochure, p54) (Nussbaum, Peter 2010, p.7)

The CIELAB coordinates L* (lightness), a* (red-green) and b* (blue-Yellow) can be obtained by mathematical transformation and computation of the X, Y and Z tristimulus values(Color & Quality, Expert Guide, Heidelberger Druckmaschinen A G, 2008, pp.1- 4). Here the chromaticity diagram is in the shape of a circle as shown below (Cf. Konica Minolta Brochure, p. 18):

4 The delta E value (ΔE)

The ΔE value is used to enable the distance / difference between two colours to be defined. It corresponds to the smallest distance between two hues, the human eye can discern because perception of the colour difference is dependent on the hue. The reason for this is that the human eye is much more sensitive in the blue-green region than the red region. The eye is most sensitive in

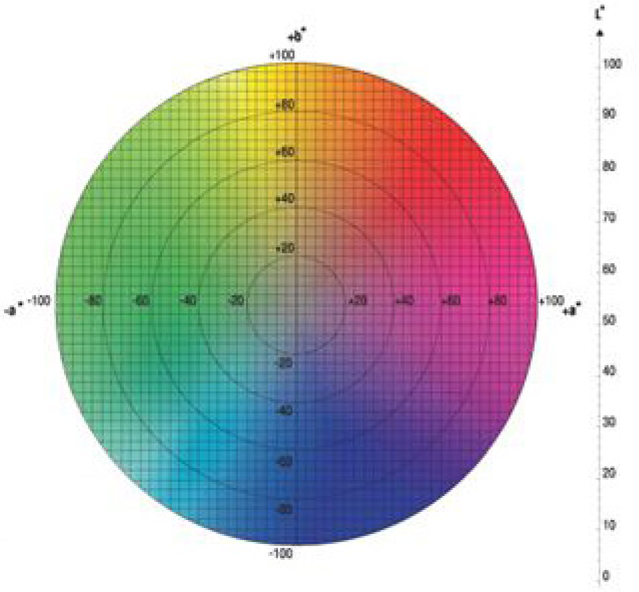

*Figure 1: Graphical presentation of CIE L*a*b* Colour Space cross section*
Source: www.printer-publisher.ruprint.ru/stories/24/68_6.php, Dated 23/05/2015, 17:22

the neutral which is called grey range (Cf.Konica, Minolta Brochure, p.55).

The following colour difference ΔE formula is used in this study with production print deviation/variation tolerance for solids as per new ISO 1264-2 20013 specifications (www.mellowcolour.com/post.html/24/, Dated 24/05/2015, 17:11) where the L*a*b* colour space indicates the degree of colour difference but not the direction, it is defined by the following equation:

$$\Delta E^*_{ab} = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \qquad (2)$$

Where ΔL*, Δa*, Δb*: Difference in L*, a*, and b* values between the specimen colour and the target colour. However this formula can only give us a quantitative number which doesn't mean the Delta E variation visible and perceived by human is acceptable. Thus colour scientists modified this basic equation from time to time and the present worldwide accepted equation to calculate Delta E is CIE 2000 colour difference formula. This formula was developed to resolve the problem of evaluating difference between colour measurement by instrument and by the human eye originated due to difference in the shape and size of the colour discrimination threshold of the human eye.

It defines a calculation so that the difference of both becomes close to the colour discrimination threshold of the human eye in the CIE Lab system. Here as weight is assigned to ΔL* (lightness difference), ΔC* (saturation difference) and ΔH* (hue difference by using correction weighting coefficients SL, SC, and SH which includes the effects of lightness L*, saturation C*. and hue angle i.e., h. along with taking in consideration of CIELAB colour discrimination threshold of human eye like Saturation dependency, Hue dependency, and Lightness dependency. (Cf.Konica Minolta brochure, p.52)

Here ΔE_{00} is represented with an ellipse which is similar to the colour discrimination threshold of human eye having the major axis in the direction of saturation and in lower saturation region the weighing coefficients SL, SC. and SH are tend towards numeric value of one so ellipse becomes more circular. In case or higher saturation region SC greater than other coefficients than the ellipse take longer shape towards saturation. Due to consideration of Hue angle and parametric constants kL, kC and kH this formula becomes capable of taking care of of the human eye on the colour space of CIE Lab (L*a*b* colour space) including the consideration of Change in the direction of the colour discrimination threshold around the hue angle of 270 degrees (blue) (deviation from the direction of saturation). (Cf.Konica Minolta brochure, p.56)

$$\Delta E_{00} = [\ (\Delta L'/ kL.SL)^2 + (\Delta C'/ kC.SC)^2 + (\Delta H'/ kH.SH)^2 + \{RT\times\ (\Delta C'/ kC.SC)^2 \times (\Delta H'/ kH.SH)^2\}\ ]^{1/2} \qquad (3)$$

Even with this also the actual acceptance of colour cannot be considered as the ultimate and best result. The reason for this is just because the human acceptance is subjective in nature.

5 Research methodology

First of all a suitable master was prepared after considering many changes with a continuous wedge of solids along with dot gain. (Krishanan, A.H. 2015, p. 146) The printed sheets with different densities from one end to other end keeping the variation with 0.05 densities. The wet densities were also measured and sheets were allowed to dry. After 8 hours, the 'L*a*b*' and 'Print Contrast' are measured on each density patches, and the curve depicting different lab and contrast values are generated.

After final printing experiment stage, the initial identification of standard observers was required (ASTM 0001). For this, colour strips of Cyan, Magenta and Yellow were cut from the printed sheets and alternate patches were pasted on colour caps. These caps were numbered from 1 to 10 from dark to light density and same strips were pasted on a black chart and three randomly cut colour strips were prepared of each colour as shown in Figure 2. The different persons were asked to arrange the caps in a descending order i.e. from dark to light for each colour. The 30 persons who arranged more than 50% of each colour shade separately and accurately were considered suitable for final online Fransworth-Munsell 100 Hue Colour Vision Test for further judgment. In online 'Fransworth-Munsell 100 Hue Colour Vision Test' the physical colour caps of D15 portable test are replaced with the four row of colour plates consisting of 88 different plates required to be arranged in above mentioned four distinct rows in which first and last plate of each

Figure 2: Cap model developed on the basis of Fransworth-Munsell 100 Hue Colour Vision Test using actual prints from experiments

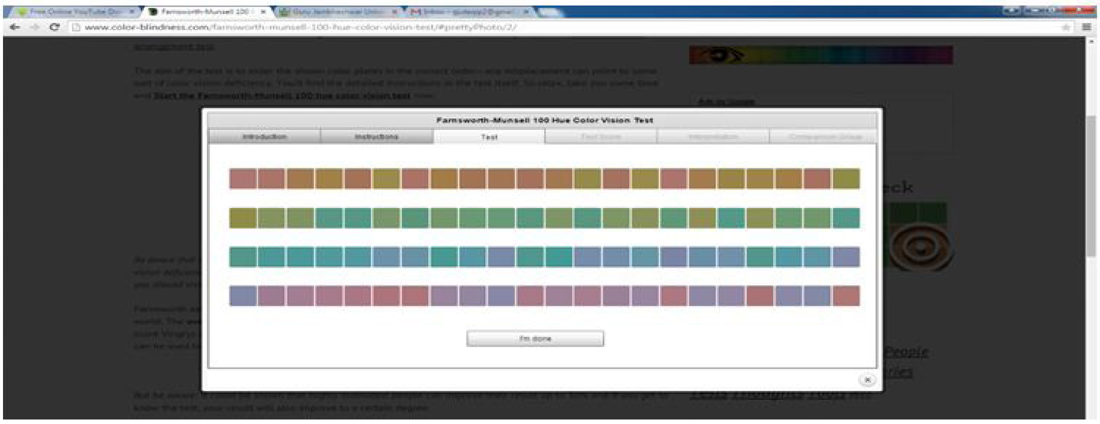

Figure 3: Online Fransworth-Munsell 100 Hue Colour Vision Test window screen shot
Source: www.color-blindness.com/farnsworth-munsell-100-hue-color-vision-test/#prettyPhoto/2/ Date 1/06/2015, 16:30

row is fixed and set correctly for using it as anchor plates as shown in Figure 3 (www.color-blindness.com/farnsworth-munsell-100-hue-color-vision-test/#prettyPhoto/2/). The in-between plates are mixed randomly and the person appearing for the hue test is required to move the plates with the help of cursor in the expected order of variation and hue change. The person can re-arrange the plate at any point of confusion within the rows and after completion of the test it provides the overall error score of the individual in which the person with error score of 70 is considered with the normal colour vision. Therefore, during the hue test of the standard observers it was found that the difference of error score of same observer in first and second attempt of the test was around 10. Therefore, all the standard observers were selected within the maximum error score of 60 and below to it by subtracting the error score of 70 by variation in error score i.e. 10 in first and second attempt.

To make the analysis more justified by human perception (Dugay. F. 2006-7) the same sheets were given to "10 Standard Observers" and their visual assessments and judgement for selection of best hue patch by elimination method were compared. While doing the experiment a '1 minute' gap was intentionally provided in-between observations to completely avoid any involved eye fatigue. All the parameters like Paper, Ink, Measuring Conditions, and Measuring Instruments etc. were maintained in compliance with ISO specifications.

The experiment was carried out with following material and specifications.

Sr. No.	Operation/ Material	Machine/Equipment/Company	Specification/Condition
1	Designing	PC	Dell
2	Paper	Bilt	C2S Art Paper Royal Gloss 130 GSM
3	Ink	LT Spectro	Process Colour
4	Plate	TechNova	Cronos Gold 530x644x0.28mm
5	Chemicals	TechNova	
6	Plate Making	CTP	
7	Printing Machine	ADAST Dominant 725 P	Two colour, Operating speed 3000IPH, size:19x26 inch
8	Room Temperature	28-30 °C	
9	Relative Humidity	45-46 persent	
10	pH	5.1	
11	Colour Mesuerment (With four underlying Black Sheets)	X-Rite eXact	D-50
12	Colour Vision Test	Initial -	Manual
		Final -	Fransworth-Munsell 100 Hue Color Vision Test
13	Colour Judgment (With four underlying White Sheets)	X-Rite (Lighting Booth)	Macbeth Lighting Viewing angle 2°

5.1 TEST CHART

The elements of the test chart used in this study consists

1. Solid bars of CMYK.

2. Colour control strip along the length Colour control strip along the length (Digital Print control strip for electronic Imposition / Thomson Press).

3. Solid triangles of 155 square cm area for each triangle in which consumption of ink is high to low from left to right for Y&C and opposite for M&K.

4. Solid colour 19 patch strip of 1.3 x 2.5 cm of CMYKG colours.

5. Ugra/ Slur doubling patches of YMC and K colours and screen (Twice).

6. Ink key zone wise CMYK patches of 75 % dot patches for all 19 ink zones.

7. 2-100% dot patch strip of RGBCMYK dot patches.

8. Logo of GJUS&T and Wuppertal University.

9. Plate blanket pressure and ink fill indicator patch.

10. Colour registration marks.

Figure 4: Test Chart

6 Data collection and analysis

the contrast, minimum Delta E value and the Delta E value selected by Maximum standard observers is here termed as ten point Standard Observers Visual Perception(SOVP) Index for first sheet along with the cell colour and details of abbreviations is tabulated and their trends are graphically represented below:

Minimum Delte E Patch value	Delte E Patch value selected value by Maximum SO	U/A- Unacceptable	A- Acceptable	G- Good	E- Excellent

Table 1. Cyan Patch SOVP Index

SN10/ Patch No.	Cyan Contrast	Cyan Delta E	SOVP INDEX
1	53.4	14.85	U/A 10
2	48.48	12.6	U/A 10
3	41.2	10.17	U/A 10
4	34.81	8.74	U/A 10
5	28.73	7.7	U/A 10
6	21.83	5.94	U/A 10
7	15.57	4.68	U/A 10
8	5.79	2.52	U/A 10
9	1.14	1.7	A/1
10	5.18	1.56	G/2
11	9.2	2.02	E/5
12	13.85	4.72	U/A 9
13	17.44	8.19	U/A 9
14	18.63	8.58	U/A 10
15	21.64	8.84	U/A 10
16	22.99	10.59	U/A 10
17	25.59	12.17	U/A 10
18	27.7	14.08	U/A 10
19	30.26	16.31	U/A 10

Table 2. Magenta Patch SOVP Index

SN10/ Patch No.	Magenta Contrast	Magenta Delta E	SOVP INDEX
1	49.14	19.98	U/A 10
2	49.03	15.51	U/A 10
3	45.59	11.47	U/A 10
4	43.56	9.27	U/A 10
5	41.24	7.34	U/A 10
6	39.31	2.46	E/4
7	34.83	2.75	A/2
8	30.94	2.21	A/2
9	26.77	2.15	G/2
10	27.02	4.12	U/A 10
11	24.06	7.42	U/A 10
12	20.99	8.73	U/A 10
13	17.32	10.27	U/A 10
14	16.03	10.87	U/A 10
15	10.66	13.14	U/A 10
16	10.43	13.06	U/A 10
17	6.76	14.63	U/A 10
18	4.86	15.57	U/A 10
19	4.83	16.71	U/A 10

Table 3. Yellow Patch SOVP Index

SN10/ Patch No.	Yellow Contrast	Yellow Delta E	SOVP INDEX
1	37.38	20.7	U/A 10
2	37.27	20.18	U/A 10
3	34.01	18.47	U/A 10
4	26.19	15.36	U/A 10
5	23.04	13.12	U/A 10
6	18.73	11.92	U/A 9
7	16.98	11.97	U/A 10
8	9.74	8.65	U/A 10
9	2.84	5.02	U/A 9
10	3.06	3.19	G/1
11	4.61	3.34	E/4
12	8.94	3.55	A/2
13	13.51	5.29	U/A 9
14	16.93	7.29	U/A 10
15	18	7.69	U/A 10
16	20.59	9.49	U/A 10
17	23.53	11.11	U/A 10
18	24.59	11.45	U/A 10
19	24.93	11.39	U/A 10

Table 4. Black Patch SOVP Index

SN10/ Patch No.	Black Contrast	Black Delta E	SOVP INDEX
1	36.39	3.04	U/A 10
2	33.44	2.07	U/A 10
3	30.43	2.47	U/A 10
4	29.23	2.93	U/A 10
5	29.13	2.71	U/A 10
6	28.29	3.04	U/A 10
7	29.57	2.61	U/A 10
8	28.53	2.84	U/A 10
9	30.3	2.3	E/5
10	29.51	2.4	A/1
11	30.46	1.96	G/3
12	29.95	2.1	U/A 9
13	28.07	2.98	U/A 10
14	27.32	3.39	U/A 10
15	23.03	5.38	U/A 10
16	17	8.24	U/A 10
17	9.49	11.46	U/A 10
18	5.61	13.1	U/A 10
19	2.75	16.33	U/A 10

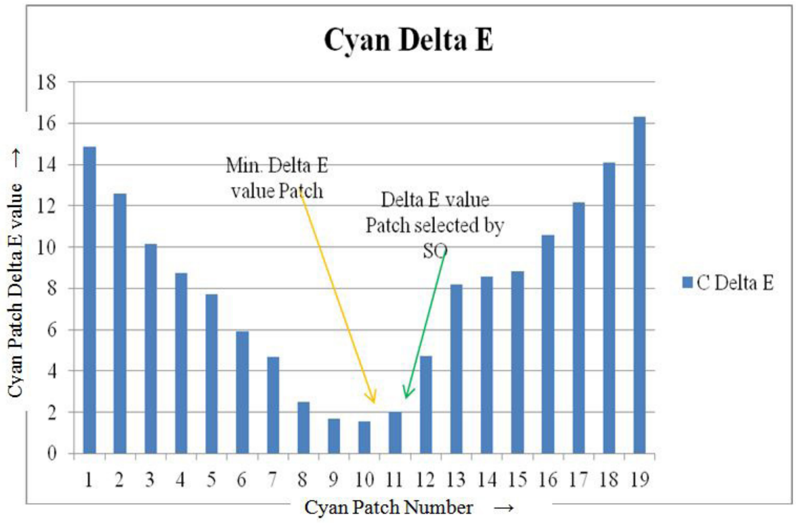

Figure 5: Delta E selection in Cyan colour, DELTA E VALUE TREND OF SELECTIONS

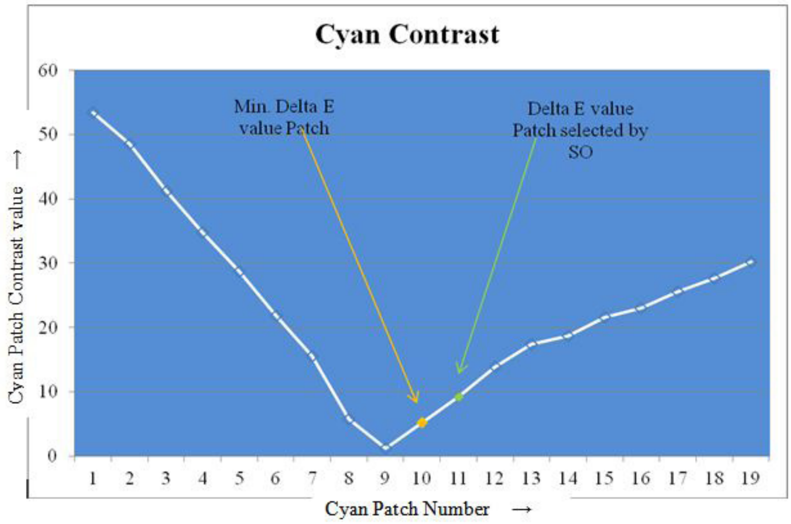

Figure 6: Contrast selection in Cyan colour, CONTRAST VALUE TREND OF SELECTIONS

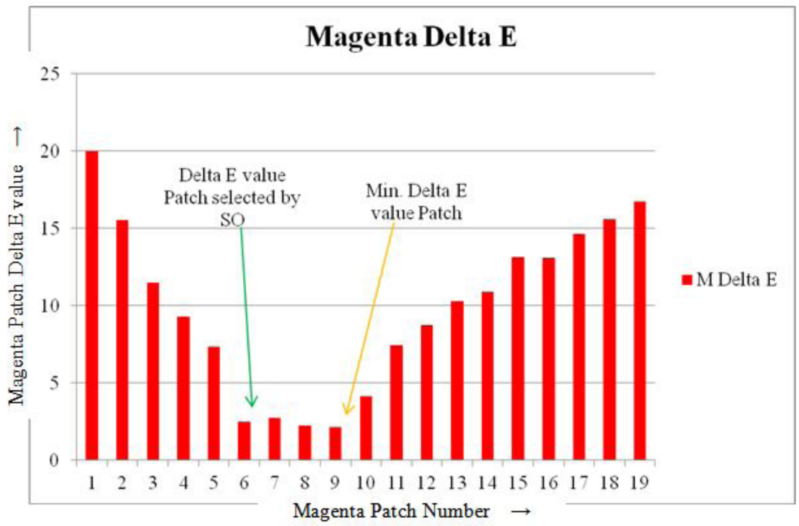

Figure 7: Delta E selection in Magenta colour, DELTA E VALUE TREND OF SELECTIONS

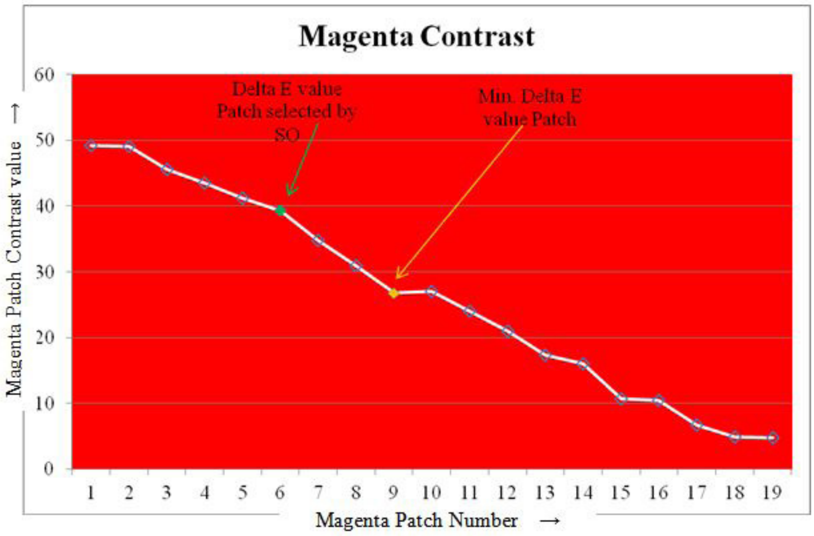

Figure 8: Contrast selection in Magenta colour, CONTRAST VALUE TREND OF SELECTIONS

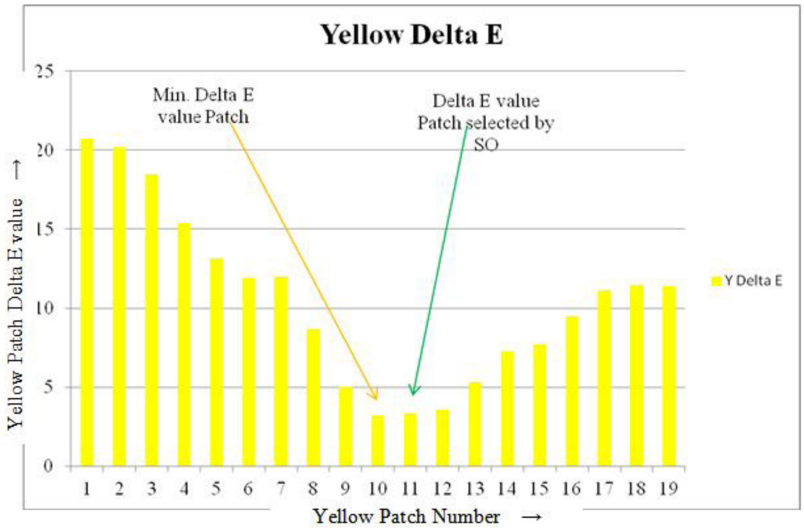

Figure 9: Delta E selection in Yellow colour, DELTA E VALUE TREND OF SELECTIONS

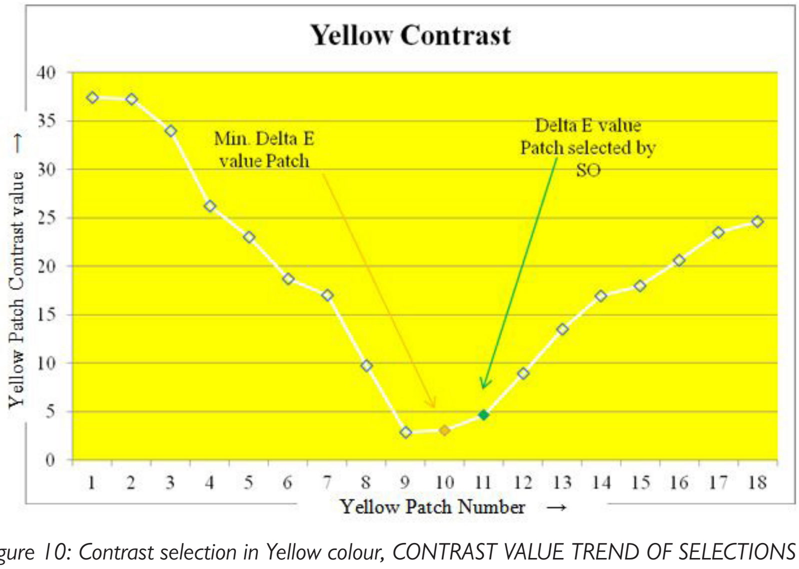

Figure 10: Contrast selection in Yellow colour, CONTRAST VALUE TREND OF SELECTIONS

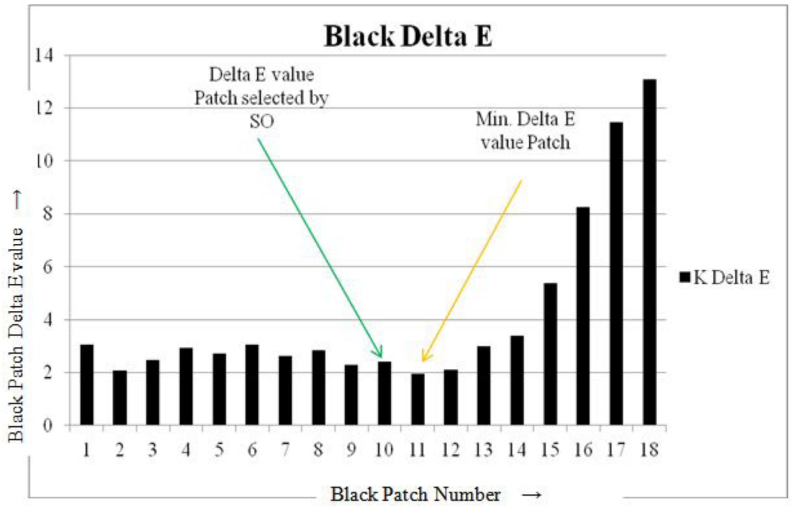

Figure 11: Delta E selection in Black colour, DELTA E VALUE TREND OF SELECTIONS

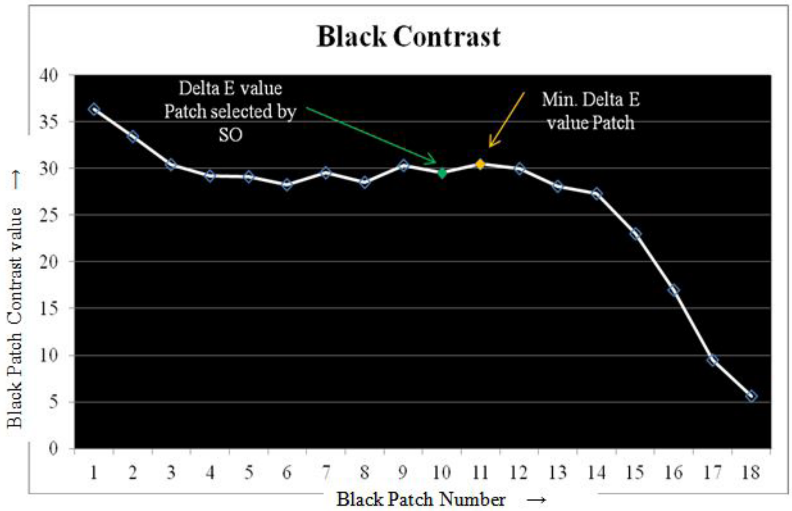

Figure 12: Contrast selection in Black colour, CONTRAST VALUE TREND OF SELECTIONS

The minimum Delta E value and the Delta E value selected by Maximum standard observers for all the ten sheets are tabulated and their trends are graphically represented below:

Table 5. Minimum ΔE value and ΔE value selected by Max. Standard Observers in CMYK Patches

Sheet No.	Min. ΔE value in Cyan Patch	ΔE value selected by Max. SO in Cyan Patch	Min. ΔE value in Magenta Patch	ΔE value selected by Max. SO in Magenta Patch	Min. ΔE value in Yellow Patch	ΔE value selected by Max. SO in Yellow Patch	Min. ΔE value in Black Patch	ΔE value selected by Max. SO in Black Patch
1	1.56	2.02	2.15	2.46	3.19	3.34	1.96	2.3
2	2.34	2.77	2.08	2.47	2.8	3.36	2.27	2.42
3	2.41	2.42	1.83	2.18	2.84	3.31	1.88	2.23
4	2.41	2.69	1.82	2.51	3.09	3.34	1.78	2.64
5	2.18	2.69	1.89	2.09	2.25	2.74	2.34	3.33
6	2.27	2.55	2	2.54	3.38	3.39	1.71	2.58
7	2.29	2.58	1.73	2.58	2.92	3.39	1.92	2.02
8	2.25	2.38	2.51	2.69	2.75	3.2	2.26	2.61
9	2.42	2.5	2.02	2.52	3.09	3.41	2.12	2.77
10	2.11	2.67	2.15	2.61	3.14	3.33	2.07	2.2

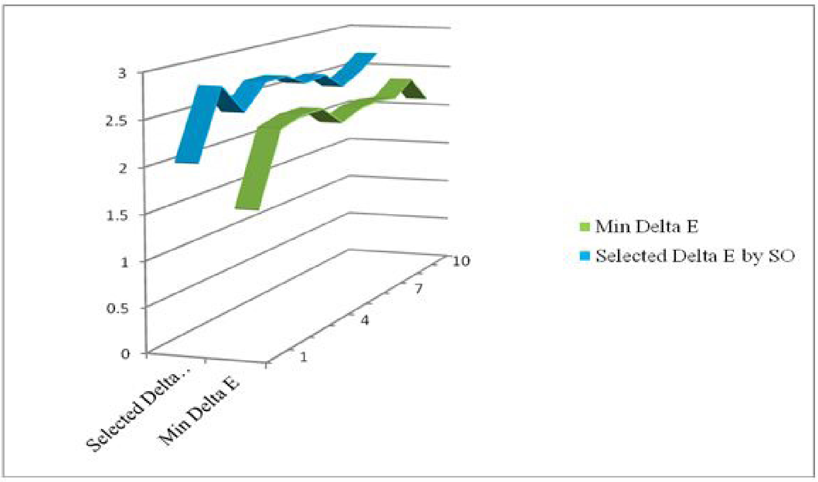

Figure 13: Minimum Delta E value and the Delta E value selected by Maximum SO in Cyan colour, CYAN PATCHES DELTA E VALUE SELECTION TREND OF ALL TEN SHEETS

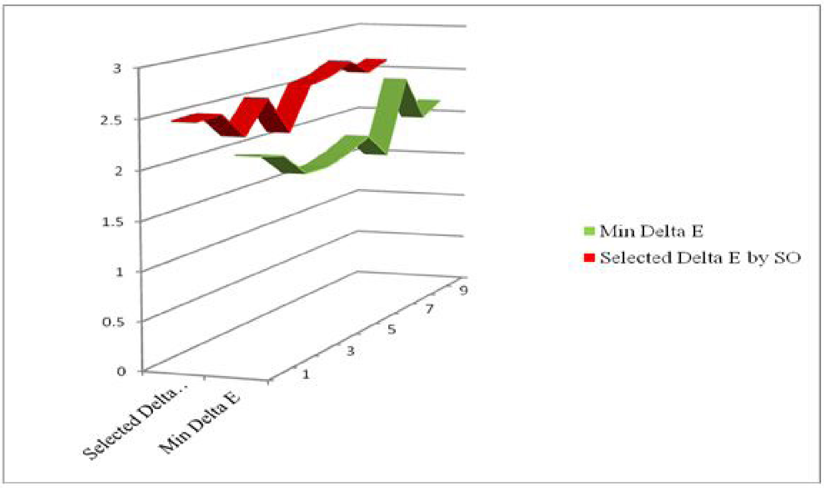

Figure 14: Minimum Delta E value and the Delta E value selected by Maximum SO in Magenta colour, MAGENTA PATCHES DELTA E VALUE TREND OF ALL TEN SHEETS

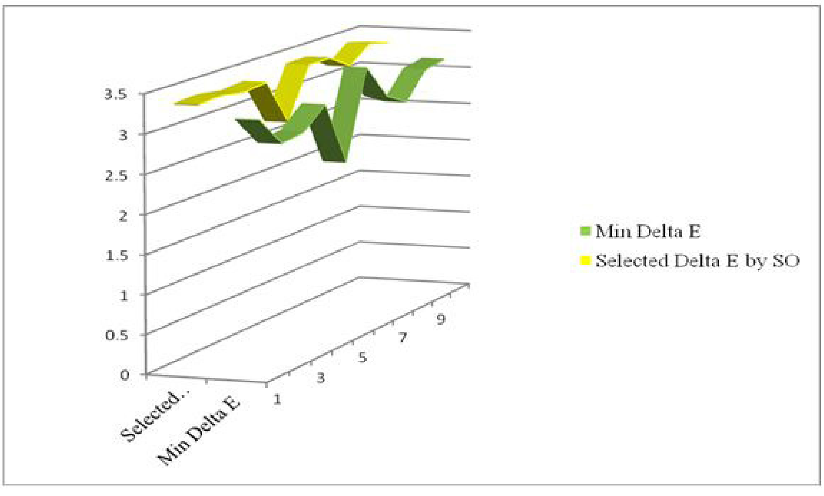

Figure 15: Minimum Delta E value and the Delta E value selected by Maximum SO in Yellow colour, YELLOW PATCHES DELTA E VALUE TREND OF ALL TEN SHEETS

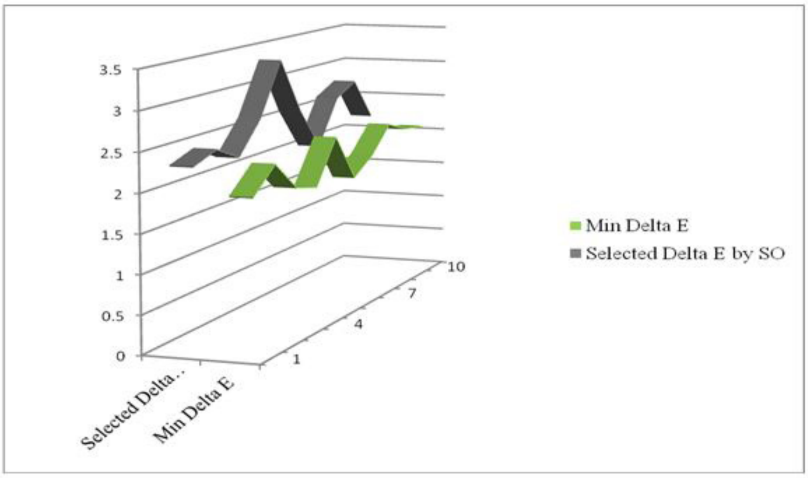

Figure 16: Minimum Delta E value and the Delta E value selected by Maximum SO in Black colour
BLACK PATCHES DELTA E VALUE TREND OF ALL TEN SHEETS

7 Result analysis and inference

It is observed that almost in all the cases and for all colours i.e. CMYK, preference of the Standard Observers are for Delta E Value leading to the higher contrast value instead of Minimum Delta E with less contrast value.

Print Contrast is high at three places under the acceptable variation tolerance for production print (Refer Table 2), Delta E is minimum (2.15) at one point and Human Perception is at one of the highest print contrast, but we go by a pragmatic approach to find out the right printing conditions in this "Hybrid Model Approach" (HMA) which was perfectly satisfying standard observers' best acceptance levels. This fulfills all the three decisive parameters which are the real deciding points in the final acceptance. Thus we decided to combine subjective and objective approach to arrive at findings and then take a pragmatic approach to get the best possible result therefore this method proved to be an appropriate way in achieving the best, consistent print match between the original and the print. The Table 2 provides the details for Magenta ink as it is the toughest ink to match and print due to its pigmentation properties.

8 Conclusion

This "Hybrid Model Approach" (HMA) will help us to arrive at the most convincing, measurable and perceptually acceptable print result which will be the closest match to the original by clubbing the best of "CIE L*a*b*, Contrast Method and Standard Observers Visual Perception as there are positives and negatives in all these three when you approach individually. For example the Lab measurement can only tell us the "Ink Contamination" during continuous print run and contrast measurement can tell us which combination can really give a "Punch" to the print and off course human perception alone can be influenced by mood, background, fatigue etc.

The "Hybrid Model Approach" (HMA) of identifying the 'most nearer print result' to the 'original' and will provide us the best of the best possibility, acceptability, consistency in print quality with least pain in controlling dot gain and maintaining the best print contrast.

9 Future scope of research

HMA approach towards reaching most convincing, measurable and acceptable Grey balance should be explored as further scope of research.

10 Acknowledgement

The research work presented has only been made possible through the help and support received from number of remarkable individuals, I take opportunity to acknowledge the academic and emotional support of Prof. Peter Urban, Wuppertal University, Germany, and Mr. Ron Fuller, Director, SANDAN DRY OFFSET, U.S.A., for his support in master preparation.

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