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Analysis of the Black and White Image Recording of the Converted RGB Photographic Image

Darija Ćutić, Miroslav Mikota*, Maja Turčić

Abstract: A digital camera is generally used for digital recording of photographic images in the RGB system. When such a multicoloured photographic image is converted to black and white using the standard Grayscale conversion in Adobe Photoshop, the colour information, expressed as R, G and B channel values, is lost. This paper analyses the darkening caused by different conversions of the RGB record of a photographic image to a black and white image record. The conversions were performed on three photos, with 10 random colours separated for each photo before conversion. After conversion, the *L* parameter, which indicates the brightness value, was analysed. The changes in the *L* parameter due to different methods of photo conversion from multicolour to black and white, such as desaturation, extraction of the R channel, extraction of the G channel and extraction of the B channel, were also analysed.

Keywords: black and white image; Grayscale system; *L* parameter; photo conversion; RGB system

1 INTRODUCTION

The digital multicolour records of photographic images are generally recorded in RGB colour spaces such as sRGB or Adobe RGB. The main purpose of the RGB colour system is to reproduce the photograph on the screen [1-3]. The photograph is then converted to black and white as this allows the manipulation of the photograph to achieve a sufficient range of tones to control blackness and emphasise the contrast between light and dark tones [4, 5]. When converting a photo from a multicolour to a black and white system, certain details are lost and the display information is reduced. This loss is caused by the reduction of the colour range [6-8]. In the RGB system, the colours contain parameters that determine the amount of red, green and blue components for each RGB channel [9, 10]. When converting an image from a multicolour to a black and white display with a standard Grayscale conversion, the parameter L from the $L^*a^*b^*$ system, which defines the brightness, remains the same [11, 12].

To perform a more detailed analysis, the L parameter was observed in other methods of conversion from a multicolour to a black and white display (desaturation, extraction of the R channel, extraction of the G channel and extraction of the B channel) [13, 14]. Colours that have the same L parameter in the RGB system are displayed in the same grey colour when we convert the photograph to the standard Grayscale system. The display information is lost because conversion to a black and white system using the standard Grayscale conversion causes the reduction of the RGB colour system. In this paper with three different multicoloured photos, 10 colours were separated for each of these photos. The colours were observed in different types of conversion to a black and white display and the change in the parameter L after conversion was analysed. Thus, a new parameter ΔL was determined to monitor the difference and change in the parameter L.

1.1 Conversion of a Photographic Image from a Multicolour RGB System to a Black and White Image Record

There are several ways to convert a photographic image from multicolour to black and white. The basic method of converting the original multicolour image to a converted black and white image is the standard Grayscale conversion, in which the photo is transferred from the RGB system to the Grayscale system. In this conversion mode, the brightness of the grey colour is determined by the parameter L, which in this case remains the same for the original and the converted image [15].

Other conversions of photographic images from RGB multicolour to black and white leave the images in the RGB system. One of these is desaturation, i.e. reducing the colour saturation to a minimum, which converts the image to black and white. There are other possibilities such as separating the red, green or blue channels of the image records, resulting in a separate black and white representation.

1.2 Monitoring the *L* Parameter

The parameter L determines the darkening or brightness of the grey colour in the black and white display. The L parameter only remains the same for the standard Grayscale conversion of the original multicolour image into a black and white image. With the other methods mentioned for converting multicolour images to black and white, the L parameter is also changed for some, but not all colours. By monitoring the parameter L, the optimal conversion method for a photo can be determined depending on the subject of the photo and the proportion of a particular colour in the RGB system.

If we compare the L parameter of the original RGB image record with the L parameter of the converted black and white image records, the increase or decrease of the L parameter can be expressed by ΔL.

Accordingly, ΔL can be expressed by the equation:

$$\Delta L = L_{\mathrm{RGB}} - L_{\mathrm{BW}} \tag{1}$$

Where L_{RGB} is a parameter that specifies the brightness of an RGB multicolour image, and L_{BW} is a parameter that specifies the brightness of a black and white image that has been converted using one of the various conversions (1). According to specific conversion L_{BW} can be shown as L_{GS}, for standard Grayscale conversion to black and white, L_{DES} for conversion to black and white with desaturate tool, $L_{R\text{-}C}$ for conversion to black and white via extracting the red channel, $L_{B\text{-}C}$ for conversion to black and white via extracting the blue channel or $L_{G\text{-}C}$ for conversion to black and white via extracting the green channel.

L_{RGB} and L_{GS} which is parameter of Grayscale standard conversions have the same L parameter value as it is shown in next equation:

$$L_{RGB} = L_{GS} \quad (2)$$

If the ΔL parameter is greater than 10 in different conversions compared to L_{RGB} or L_{GS}, this difference is noticeable and affects the contrast in different conversions.

2 EXPERIMENT PREPARATION

2.1 Colour Separation

For the experiment, three photographs were taken in which the separation of randomly selected colours from the recorded data set was performed, and the specified separated colours were observed after conversion to a black and white display. Figs. 1, 2 and 3 show randomly separated colours from photographic images. Fig. 1 shows the first photo, in which the main object is a portrait. The skin contains a handful of red tones, which is why this subject was chosen.

Figure 1 First photography with ten separated colours

In Fig. 2 you can see how the sea was chosen as the main object of the picture because it is rich in shades of grey and blue. In Fig. 3, the main object in the photo is a human figure in the greenery of the park, and this scene was chosen to observe the photo, which is rich in blue tones.

Figure 2 Second photography with ten separated colours

Figure 3 Third photography with ten separated colours

2.2 Image Conversion to Black and White

All photos taken were converted to black and white using five different conversion methods: "Desaturate", "Grayscale", "R-channel", "B-channel" and "G-channel". The "Desaturate" method converts a multicoloured photo to black and white by reducing the saturation of the entire photo to zero, but leaving the photo in the RGB system. The "Grayscale" method is a standard method for converting a photo to black and white, in which the photo is converted from the RGB system to the Grayscale display system. In the "R-channel" method, the red channel is extracted while the green and blue channels are switched off so that they are not visible in the photo. The "G-channel" conversion method extracts the green channel, which is the only one visible, while switching off the display of the red and blue channels. The last method for converting a multicolour image to black and white is the "B-channel" method, in which we separate the blue channel for the photographic capture of the image and set it as the only visible channel, while switching off the red and green channels in this capture.

Fig. 4 shows the conversion of the first photo to black and white using five different conversion methods, while Fig. 5 shows the conversion of the second photo and Fig. 6 the conversion of the third photo.

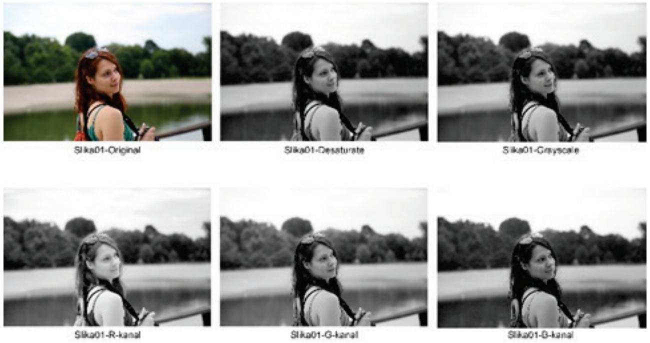

Figure 4 First photography converted to black and white with five different methods

Figure 5 Second photography converted to black and white with five different methods

Figure 6 Third photography converted to black and white with five different methods

3 RESULTS VALUES OF THE SEPARATED COLOURS FROM CAPTURED PHOTOGRAPHS

The following tables show the values corresponding to the separated colours. The values were measured using Adobe Photoshop software. The red, green and blue components in the RGB system and the L value are measured for each colour.

After different types of conversion to black and white, the L values were measured for each converted display in order to compare them and analyse the changes.

Tab. 1 shows the measured values for the first five separated colours of the first photo, while Tab. 2 shows the other five separated colours of the first photo. Tab. 3 and Tab. 4 show the measured values for the ten separated colours from the second photo. Tab. 5 and Tab. 6 show the measured values for the separated colours of the third photo.

Table 1 Table values of first 5 separated colours from first photography

Photography 1 – first 5 separated colours					
RGB colour code	#49271d	#b4866f	#333d34	#3d4b28	#4a887d
R	73	180	51	61	74
G	39	134	61	75	136
B	29	111	52	40	125
L_{RGB} (RGB)	20	60	25	30	52
L_{GS} (Grayscale)	20	60	25	30	52
L_{DES} (Desaturate)	21	60	24	24	44
$L_{R\text{-}C}$ (R cannel)	40	79	30	35	41
$L_{G\text{-}C}$ (G cannel)	23	64	34	41	65
$L_{B\text{-}C}$ (B cannel)	17	56	30	24	61

Table 2 Table values of second 5 separated colours from first photography

Photography 1 – second 5 separated colours					
RGB colour code	#d4aa94	#914f51	#9d9789	#6a625f	#d2624a
R	212	145	157	106	210
G	170	79	151	98	98
B	148	81	137	95	74
L_{RGB} (RGB)	73	42	63	42	56
L_{GS} (Grayscale)	73	42	63	42	56
L_{DES} (Desaturate)	73	47	61	42	59
$L_{R\text{-}C}$ (R cannel)	88	68	71	54	88
$L_{G\text{-}C}$ (G cannel)	76	43	70	51	50
$L_{B\text{-}C}$ (B cannel)	68	44	65	50	40

Table 3 Table values of first 5 separated colours from second photography

Photography 2 – first 5 separated colours					
RGB colour code	#73abe4	#3c2e2b	#525e4a	#c0a9a3	#3a5280
R	115	60	82	192	58
G	171	46	94	169	82
B	228	43	74	163	128
L_{RGB} (RGB)	68	20	38	71	35
L_{GS} (Grayscale)	68	20	38	71	35
L_{DES} (Desaturate)	70	21	36	72	39
$L_{R\text{-}C}$ (R cannel)	57	34	44	82	33
$L_{G\text{-}C}$ (G cannel)	76	27	49	75	44
$L_{B\text{-}C}$ (B cannel)	93	25	41	74	62

Table 4 Table values of second 5 separated colours from second photography

Photography 2 – second 5 separated colours					
RGB colour code	#9ec5e2	#857671	#1e2e0a	#5a4b44	#272935
R	158	133	30	90	39
G	197	118	46	75	41
B	226	113	10	68	53
L_{RGB} (RGB)	77	51	17	33	17
L_{GS} (Grayscale)	77	51	17	33	17
L_{DES} (Desaturate)	78	52	10	34	19
$L_{R\text{-}C}$ (R cannel)	72	64	18	47	23
$L_{G\text{-}C}$ (G cannel)	84	58	27	41	24
$L_{B\text{-}C}$ (B cannel)	92	56	3	38	31

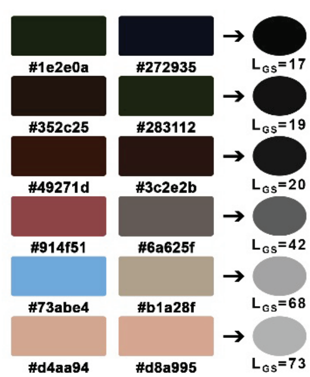

Figure 7 Results of RGB conversion to black and white with the emphasized value of the L Grayscale parameter (L_{GS})

Table 5 Table values of first 5 separated colours from third photography

Photography 3 – first 5 separated colours					
RGB colour code	#352c25	#283112	#8c917d	#252a16	#4e632b
R	53	40	140	37	78
G	44	49	145	42	99
B	37	18	125	22	43
L_{RGB} (RGB)	19	19	59	16	39
L_{GS} (Grayscale)	19	19	59	16	39
L_{DES} (Desaturate)	18	13	56	12	30
$L_{R\text{-}C}$ (R cannel)	31	24	66	22	42
$L_{G\text{-}C}$ (G cannel)	26	29	68	25	51
$L_{B\text{-}C}$ (B cannel)	22	9	61	12	25

Table 6 Table values of second 5 separated colours from third photography

Photography 3 – first 5 separated colours					
RGB colour code	#70724d	#b1a28f	#301814	#355f5d	#d8a995
R	112	177	48	53	216
G	114	162	24	95	169
B	77	143	20	93	149
L_{RGB} (RGB)	47	68	12	37	73
L_{GS} (Grayscale)	47	68	12	37	73
L_{DES} (Desaturate)	40	66	13	31	74
$L_{R\text{-}C}$ (R cannel)	56	78	28	31	89
$L_{G\text{-}C}$ (G cannel)	57	73	14	49	75
$L_{B\text{-}C}$ (B cannel)	42	67	11	49	69

4 DISCUSSION

In all tables, the values where the ΔL parameter exceeds the value of 10 are marked with orange text.

Tab. 1 and Tab. 2 refer to the first photograph which contains many red tones due to the portrait photography. The deviation of the *L* parameter becomes visible exactly when the image is converted to black and white by extracting the R channel (red channel). In Fig. 1 we can see the colours that were separated, namely the first (#49271d), second (#b4866f), sixth (#d4aa94), seventh (#914f51), ninth (#6a625f) and tenth (#d2624a) colour. If we look at the separate colours listed in Fig. 1, we can see that they all contain a certain amount of red colour, i.e. if we look at the R value in the listed tables, it is higher than the G and B value in the table for all colours.

Also, the increased values of the *L* parameter in Tab. 1 for the fourth (#3d4b28) and fifth (#4a887d) separated colours containing green show that the value of the *L* parameter increases exactly when the image is converted to black and white using the G-channel (green channel) extraction method. If we look at the G value in Tab. 1 for these colours, we see that it is higher compared to their R and B values in the original photographic record, which means that they contain mainly green colours in their composition.

In the case of the third (#333d34) and eighth colours (#9d9789), there was no significant change in the *L* value in the different conversions of the image to black and white, and when the R, G and B values of these colours are examined in Tab. 1 and Tab. 2, it can be concluded that neither colour dominates over the others, so it is assumed that there was therefore no significant change in the *L* parameter.

In Tab. 3 and Tab. 4, we can analyse the increase in the *L* value for the separated colours of the second photography, which contains many shades of blue. We can see the increase in the *L* parameter in Tab. 3 for the first (#73abe4) and fifth colour (#3a5280) and in Tab. 4 for the sixth (#9ec5e2) and tenth colour (#272935). All the colours listed have a more dominant B value compared to the R and G values of the original photographic record, as can be seen in Tab. 3 and Tab. 4, confirming that they have mainly blue colours in their composition. Similarly, the *L* value is significantly higher when the image is converted to black and white using the B channel (blue channel) extraction method.

In Tab. 3, the second (#3c2e2b) and fourth colours (#c0a9a3) and in Tab. 4, the seventh (#857671) and ninth colours (#5a4b44) show an increase in the *L* parameter when they are converted from a multicolour to a black and white image using the R-channel extraction method. If we check the amount of R colour in Tab. 3 and Tab. 4, we can see that the R value of these colours is higher than the G and B values of the original photographic record of the image.

In Tab. 3, the third colour (#525e4a) has an increased *L*-parameter when the image is converted from multicolour to black and white using the G-channel extraction method. Looking at the original record of the image of this colour in Tab. 3, we can see that the G value is higher compared to the R and B values of the colour.

Tab. 4 shows that the eighth colour (#1e2e0a), when converted from a multicolour to a black and white image using the B-channel extraction conversion method, has an *L*-value up to five times lower than the *L*-value of the original photographic image record.

If we look at the R, G and B values of the original record in Tab. 4, we see that the B value is three times smaller than the R value and four times smaller than the G value.

In Tab. 5 and Tab. 6 we can analyse the behaviour of the *L* values for the colours separated from the third photo. The separated colours can be seen in Fig. 3 and are mainly dominated by a green tone. It is interesting to see that only the fifth colour (#4e632b) in Tab. 5 shows an increase in the *L* parameter when a multicolour image is converted to black and white using the G-channel extraction method. If we examine the R, G and B values of the original image record for the given colour, we can see that the G value is the highest.

In Tab. 6, for the ninth colour (#355f5d), we see an increase in the *L* parameter when converting a multicolour image to black and white using the G-channel extraction method and the B-channel extraction method. If we examine the R, G and B values of the original image record for the given colour, we can see that the G and B values are very similar, and almost double compared to the R value.

In Tab. 5, the first colour (#352c25) and in Tab. 6, the eighth colour (#301814) and the tenth colour (#d8a995) show a visible increase in the *L* parameter when they are converted from a multicolour image to black and white using the R-channel extraction method. When we examine the R, G and B values in Tab. 5 and Tab. 6 for the original image record for the specified colours, we can see that the R value is higher compared to the G and B values.

In Tab. 5, when converting an image from a multicolour to a black and white record using the B-channel extraction method, the second colour (#283112) and the fifth colour (#4e632b) have an *L*-parameter twice as large as the original multicolour image record. If we examine the R, G and B values of the colours listed in Tab. 5 in the original image record, we can see that the B value is up to two times smaller compared to the R and G values.

It is interesting to examine the behaviour of the L parameter in the standard Grayscale conversion of a multicolour image to black and white, as Fig. 7 shows that in these 30 separate colours, 6 colour pairs were converted to the same grey colour. The colour space that is showed on Fig. 7 before conversion is RGB colour space and on the right-side Fig. 7 shows converted Grayscale colour space and the brightness parameter L_{GS}. We follow the L_{RGB} and L_{GS} parameters, which are the same, so that certain colours that are visually different in the RGB system become the same grey colour in the standard Grayscale conversion to black and white due to the same L parameter.

The RGB colours #1e2e0a and #272935 have the same shade of grey with the L_{GS} value 17 when converted to black and white using the standard Grayscale conversion. The RGB colours #352c25 and #283112 become the same grey colour with the L_{GS} value 19 when converted to black and white with the standard Grayscale conversion.

The RGB colours #49271d and #3c2e2b become the same grey colour with the L_{GS} value 20 when converted to black and white with the standard Grayscale conversion. The RGB colours #914f51 and #6q625f become the same grey colour with an L_{GS} value of 42 when converted to black and white using the standard Grayscale conversion.

The RGB colours #73abe4 and #b1a28f become the same grey colour with an L_{GS} value of 68 when converted to black and white using the standard Grayscale conversion. The RGB colours #d4aa94 and #d8a995 become the same grey colour with an L_{GS} value of 73 when converted to black and white using the standard Grayscale conversion.

For the colours indicated in Fig. 7, the tables show at which conversion to black and white ΔL exceeds the value of 10. Using these conversions would reduce the loss of contrast when converting to black and white.

Tab. 1 shows for the colour in RGB #49271d that the conversion to black and white by extracting the red channel is the one with ΔL greater than 10, since the L_{RGB} value is 20 and the $L_{\mathrm{R\text{-}C}}$ value is 40.

In Tab. 2, it can be seen for the colour RGB #914f51 that the conversion to black and white by extracting the red channel is the one with ΔL greater than 10, since the L_{RGB} value is 42 and the $L_{\mathrm{R\text{-}C}}$ value is 68. In the same table, it can be seen that for the colour in RGB #6a625f, the conversion to black and white by extracting the red channel is the one with ΔL greater than 10 because the L_{RGB} value is 42 and the $L_{\mathrm{R\text{-}C}}$ value is 54. Tab. 2 also shows that for the colour RGB #d4aa94, the conversion to black and white by extracting the red channel is the one with ΔL greater than 10 because the L_{RGB} value is 73 and the $L_{\mathrm{R\text{-}C}}$ value is 88.

In Tab. 3, for the colour in RGB #3c2e2b, it can be seen that the conversion to black and white by extracting the red channel is the one with ΔL greater than 10, since the L_{RGB} value is 20 and the $L_{\mathrm{R\text{-}C}}$ value is 34. In the same table, it can be seen for the colour in RGB #73abe4 that the conversion to black and white by extracting the blue channel is the one with ΔL greater than 10 because the L_{RGB} value is 68 and the $L_{\mathrm{B\text{-}C}}$ value is 93.

Tab. 4 shows for the colour in RGB #1e2e0a that the conversion to black and white by extracting the blue channel is the one with ΔL greater than 10 because the L_{RGB} value is 17 and the $L_{\mathrm{B\text{-}C}}$ value is 3. In the same table, it can be seen for the colour in RGB #272935 that the conversion to black and white by extracting the blue channel is that with ΔL greater than 10 because the L_{RGB} value is 17 and the $L_{\mathrm{B\text{-}C}}$ value is 31.

Tab. 5 shows for the colour RGB #352c25 that the conversion to black and white by extracting the red channel is the one with ΔL greater than 10, since the L_{RGB} value is 19 and the $L_{\mathrm{R\text{-}C}}$ value is 31. It can also be seen in Tab. 5 for the colour in RGB #283112 that the conversion to black and white by extracting the blue channel is the one with ΔL equal to 10 because the L_{RGB} value is 19 and the $L_{\mathrm{B\text{-}C}}$ value is 9, which is closest to the desired ΔL for this colour deviation.

In Tab. 6, for the colour in RGB #b1a28f, it can be seen that the conversion to black and white by extracting the red channel is the one where ΔL is equal to 10, since the L_{RGB} value is 68 and the $L_{\mathrm{R\text{-}C}}$ value is 78. In the same table, it can be seen for the colour RGB #d8a995 that the conversion to black and white by extracting the red channel is the one where ΔL is greater than 10 because the L_{RGB} value is 73 and the $L_{\mathrm{R\text{-}C}}$ value is 89.

Considering the above, it would be optimal for photographs such as the first captured photograph shown in Fig. 1, which contain many red tones, to be converted to black and white using the red channel extraction method in order to increase the contrast and obtain the widest possible tonal range in the converted black and white display.

Photographs such as the second captured photograph shown in Fig. 2, which contain many blue tones, should be converted to black and white using blue channel extraction.

Photographs that contain many green tones, such as the third captured photograph shown in Fig. 3, can be optimally converted to black and white by also extracting the red channel in order to obtain a contrast that corresponds to that of the original captured record.

5 CONCLUSION

Records of digital photography captured in the RGB system can be converted to black and white in various ways. One of the most commonly used methods for converting to black and white is the standard Grayscale conversion in Adobe Photoshop. As can be seen from the research conducted, the L_{RGB} value, which represents the L parameter for brightness in the RGB colour system, is equal to the L_{GS} value, which represents the L parameter of the converted standard Grayscale record. This confirms that in the standard Grayscale image conversion, the colour system is greatly reduced because some colours that are visually different in the RGB system become the same shade of grey in the converted standard Grayscale display because the L_{RGB} and L_{GS} parameters are the same.

Monitoring the L parameter in other conversions of multicolour digital photos to black and white, this research has shown that other methods of converting multicolour photos to black and white are more suitable than the standard Grayscale conversion if there are certain subjects in the photo that are shown by a predominant amount of one of the primary colours of the RGB system. The ΔL value, which must be greater than 10, can be used to determine which conversion is optimal for certain photos.

For photos that contain a lot of red tones in the RGB system, such as photos of human portraits or nudes, it is optimal to convert them from a multicolour system to black and white using the red channel extraction method. The $L_{\text{R-C}}$ parameter fulfils the condition that ΔL is greater than 10 compared to the L_{RGB} parameter.

For photos whose subject is the sea, for example, and which contain many blue tones, the optimum conversion from the multicolour RGB system to black and white would be the method of extracting the blue channel, as the $L_{\text{B-C}}$ parameter fulfils the condition that ΔL is greater than 10 compared to the L_{RGB} parameter.

Photos of nature taken in the RGB colour system contain a large amount of green tones. It is optimal to convert them to black and white by extracting the red channel, because ΔL is greater than 10 when we compare the $L_{\text{R-C}}$ and L_{RGB} parameters.

By using the optimal conversion method of different subjects with different predominant primary colours in the RGB system, the loss of contrast and colour space in the converted black and white system would be reduced, leaving the converted black and white record more similar to the original multicolour photographic record.

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Authors' contacts:

Darija Ćutić, senior lecturer
University of Applied Sciences Zagreb,
Vrbik 8, 10000 Zagreb, Croatia
dcutic@tvz.hr

Miroslav Mikota, PhD, associate professor
(Corresponding author)
University of Zagreb Faculty of Graphic Arts,
Getaldićeva ulica 2, 10000 Zagreb, Croatia
miroslav.mikota@grf.unizg.hr

Maja Turčić, PhD, higher lecturer
University of Applied Sciences Zagreb,
Vrbik 8, 10000 Zagreb, Croatia
mturcic@tvz.hr