COLORIMETRIC CHARACTERISATION OF TRICHROMATIC RGB DIGITAL IMAGES. I. COMPARATIVE HSL COLOUR FEATURES

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Abstract

The linear and uniform RGB colour space can include up to 255 x 255 x 255 = 16,581,375 colours, far exceeding the capabilities of the human eye in the 400 - 700 nm wavelength interval. In colour rendering technique, each pixel contains information about the trichromatic components red, green and blue, specific to additive mixes, in [r g b] form with each component value ranging between 0 and 255 or in standard form, in which case the colour cube faces are even. From the standpoint of the colour designer, any random colour can be characterised by hue, lightness and, saturation. The interpretation of the values of these basic features by digital image analysis is important in industrial practice for correcting printed designs and also for the technological analysis of print quality. The paper presents three methods of comparative analysis of trichromatic digital image and possibilities of retouching.

Keywords: colour, hue, saturation, lightness, model..RGB

The linear and uniform RGB colour space can include up to 255 x 255 x 255 = 16,581,375 colours, far exceeding the capabilities of the human eye in the 400 - 700 nm wavelength interval. In colour rendering technique, each pixel contains information about the trichromatic components red, green and blue, specific to additive mixes, in [r g b] form with each component value ranging between 0 and 255 or in standard form, in which case the colour cube faces are even.

Through the addition of black (K) in a subtractive mix in order to expand the colour palette, the following transformation relations are performed:

\[
\begin{align*}
R & = 1 - M ; \\
G & = 1 - Y ; \\
B & = 1 - C
\end{align*}
\]

\[
\begin{align*}
R & = \min(C(1-K)+K) \\
G & = \min(M(1-K)+K) \\
B & = \min(Y(1-K)+K)
\end{align*}
\]

Figure 1. The RGB colour cube

A colour \( C_{RGB} \) (102, 140, 166) within the cube may be expressed through its parts:

\[
\begin{align*}
R &= 102/255=0.40=1-C; \\
G &= 140/255=0.55=1-M; \\
B &= 166/255=0.65=1-Y,
\end{align*}
\]

considering:

MATERIAL AND METHOD

RGB trichromatic digital images

Trichromatic digital images are built on a m x n pixel network, with each pixel being assigned the triplet (r g b). The tridimensional \((..., (r, g, b))\) structure emerges. A random pixel \((i,j), i=1:n \) number of rows and \(j=1:m \) number of columns, incorporates the \( r \), \( g \), \( b \) values in the 0:255 range or in standard form in the 0:1 interval, with double accuracy, i.e. double(R, G and/or B)/255. The practical methods employed on trichromatic spectrum images R (red), G (green), B (blue), using the Matlab work environment, are described below.

The Eric Boyer - Aldo Morales Method

For the purposes of the analysis, a colour palette with the \( h, l, s \) differentiating features was

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employed, with a 108 x 339 pixels size. The WA image is uncorrected, while the WD image is corrected by MOPM (Microsoft Office Picture Manager) using the command Picture – Auto Correct.

Figure 2. Geometry of trichromatic digital images

Figure 3. Uncorrected WA image and properties

Figure 4. WD image corrected using MOPM and properties

Dimensions
339 x 108

Width
339 pixels

Height
108 pixels

Horizontal resolution
96 dpi

Vertical resolution
96 dpi

Bit depth
24

Figure 5. WA image sequence, position 15, pixel (333,101) with values [152, 49, 70]

Figure 6. WD image sequence, position 15, pixel (333,101) with values [106, 38, 53]

For the comparison the Eric Boyer – Aldo Morales method was used, by performing a pixel-by-pixel analysis based on the formula [1]:

\[ \text{mydata(DXX,DYY)} = \sum(\sum(\text{abs}(\text{double(WD) - double(WA))))), \]

for each of the three colour components:

**RESULTS AND DISCUSSION**

**Red**

![Absolute difference for Red](image)

**Green**

![Absolute difference for Green](image)

**Blue**

![Absolute difference for Blue](image)

**Analysis based on colour characteristics**

To perform the colour analysis, the specific Matlab functions `citestexy01hsl.m` and `locusimagine.m` were used.

**Whiteness of printing material**

![RGB values of the printed background](image)

Whiteness is within the 248 ...255 range for R, G, B values, with the ideal whiteness value being 255 for the three colour components.
Figure 11. LAB space luminance of pixels used in assessing printed background

In the LAB space, L values fall within a limited range.

Figure 12. Whiteness of printed background in the CIE xy space

CIE xy and CIE upvp whiteness occupy clearly defined positions, with acceptable spread levels.

Primary identification of colour positions in WA image

Figure 13. Colour position of the printed background in the CIE upvp space

Figure 14. Pixels selected from WA image to conduct colour analysis

TABLE I. SELECTIVE COLORIMETRIC CHARACTERISTICS OF WA IMAGE

<table>
<thead>
<tr>
<th>Nr.</th>
<th>RGB</th>
<th>CIE xy</th>
<th>CIE Lab</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>255 255 0</td>
<td>0.3195 0.5052</td>
<td>214.156 201.2725</td>
</tr>
<tr>
<td>2</td>
<td>153 254 0</td>
<td>0.5185 0.5317</td>
<td>214.199 201.2725</td>
</tr>
<tr>
<td>3</td>
<td>1 102 255</td>
<td>0.1933 0.2135</td>
<td>91.564 161.9062</td>
</tr>
<tr>
<td>4</td>
<td>204 55 255</td>
<td>0.2971 0.1949</td>
<td>91.562 -266.842</td>
</tr>
<tr>
<td>5</td>
<td>254 0 50</td>
<td>0.5081 0.2575</td>
<td>91.562 161.9062</td>
</tr>
<tr>
<td>6</td>
<td>254 204 263</td>
<td>0.3292 0.3296</td>
<td>91.562 161.9062</td>
</tr>
<tr>
<td>7</td>
<td>255 153 263</td>
<td>0.3292 0.3296</td>
<td>91.562 161.9062</td>
</tr>
<tr>
<td>8</td>
<td>255 180 154</td>
<td>0.3595 0.2943</td>
<td>91.562 161.9062</td>
</tr>
<tr>
<td>9</td>
<td>255 51 102</td>
<td>0.4677 0.2819</td>
<td>91.562 161.9062</td>
</tr>
<tr>
<td>10</td>
<td>254 0 50</td>
<td>0.5081 0.2575</td>
<td>91.562 161.9062</td>
</tr>
<tr>
<td>11</td>
<td>4 4 4</td>
<td>0.3127 0.3296</td>
<td>91.562 161.9062</td>
</tr>
<tr>
<td>12</td>
<td>102 0 0</td>
<td>0.6400 0.3100</td>
<td>91.562 161.9062</td>
</tr>
<tr>
<td>13</td>
<td>128 0 0</td>
<td>0.6400 0.3100</td>
<td>91.562 161.9062</td>
</tr>
<tr>
<td>14</td>
<td>204 0 51</td>
<td>0.4841 0.2441</td>
<td>91.562 161.9062</td>
</tr>
<tr>
<td>15</td>
<td>254 0 50</td>
<td>0.5081 0.2575</td>
<td>91.562 161.9062</td>
</tr>
</tbody>
</table>

Hue

Figure 15. Locus CIE xy

Figure 16. Locus CIE upvp

Figure 17. The LAB space

Hue range

Figure 18. The hue range

Saturation

Figure 19. RGB colour values of the hue range

Figure 20. L component in the LAB space of the hue range

Saturation range

Figure 23. Saturation range

Figure 24. RGB colour values of the saturation range

Figure 25. Component in the LAB space of the saturation range
Luminance

<table>
<thead>
<tr>
<th>Colour characteristic</th>
<th>Nr.</th>
<th>R</th>
<th>G</th>
<th>B</th>
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</thead>
<tbody>
<tr>
<td>hue</td>
<td>1</td>
<td>255</td>
<td>255</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>150</td>
<td>255</td>
<td>0</td>
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<td></td>
<td>3</td>
<td>0</td>
<td>100</td>
<td>255</td>
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<tr>
<td></td>
<td>4</td>
<td>200</td>
<td>50</td>
<td>255</td>
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<td>255</td>
<td>0</td>
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<td>255</td>
<td>200</td>
<td>200</td>
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<td>150</td>
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<td></td>
<td>9</td>
<td>255</td>
<td>50</td>
<td>100</td>
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<td></td>
<td>10</td>
<td>255</td>
<td>0</td>
<td>50</td>
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<tr>
<td></td>
<td>11</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
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<td>125</td>
<td>0</td>
<td>0</td>
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<td>200</td>
<td>0</td>
<td>50</td>
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<tr>
<td></td>
<td>15</td>
<td>255</td>
<td>0</td>
<td>50</td>
</tr>
</tbody>
</table>

Re-creating image WA

R(1:108,1:339)=255;
G(1:108,1:339)=255;
B(1:108,1:339)=255;
r=size(R)
g=size(G)

Accidental pixels

Background colorimetric characteristics

Re-pixelating the WA image
Sequences I, II and III

I.

>> imtool(WK)
Tools – Pixel Region (in standard form, 0:1)

Figure 39. Sequence of figure WK, standard, pixel info (333,101) [1.00 0.00 0.20]

The standard structure of image (WK) in the interval 0:1 is pure, without any border pixels.

II.

>> imtool(WK)
File – Save As WK.jpeg ( Joint Photographic Experts Group)

Figure 40. Image saved as WK, jpeg and its characteristics

III.

>> WK=imread('WK.jpg');wk=size(WK)
wk =
108   339     3
>> imtool(WK)
Tools – Pixel Region

The colour gamut of image WK.m

CONCLUSIONS

1. Trichromatic digital images with the spatial geometric structure: A=cat(3, R, G, B) are characterised by the components R (red), G (green), B (blue) as follows:
   R=A(:,:,1);
   G=A(:,:,2);
   B=A(:,:,3),
with values ranging in the 0:255 interval or in standardised form in the 0:1 interval.
Table A in standardised form serves to represent images saved with various extensions, such as .jpeg.
2. The pixel-by-pixel comparative analysis using the ERIC BOYER – ALDO MORALES method requires two tables of the same size.
3. By correcting image WA, figure 3, using Microsoft Office Picture Manager a new image is obtained, i.e. WD, figure 4, with the change in the R/G/B ratio in the structure of border pixels (outline), figure 5 and figure 6, position 15, pixel (333,101).
4. The absolute differences, determined using the ERIC BOYER – ALDO MORALES method, are up to a maximum of 5 x 10^-5, with significant changes for the Green component, figure 8.
5. In the space between colour positions (1:15), the whiteness of the background approaches the ideal levels (a value of 255 for each of the R, G, B components), figure 11, as highlighted by the chromaticity diagrams CIE xy and CIE upvp, figure 13 and figure 14, through a limited representation domain.
6. The pixels selected from image WA, figure 15, are characterised by the chromatic values in table I and represented in the diagrams and spaces specific to locus CIE xy and CIE upvp, LAB, by means of specific spatial transformations, representations 16,17,18.
7. The transverse analysis of the hue, saturation, luminance colour characteristics (h, s, l) in the original, WA image - figures 20, 24, 29 - within each colour range, a change occurs in the R/G/B ratio for positions: 1:5, 6:10, 11:15, figures 20, 25, 30. For each colour range (h, s, or l) the value L in the LAB space serves to highlight the above mentioned colour positions, figures 21, 26, 31. In the chromaticity diagrams 22, 23, 27, 28, 32 and 33, each colour position (1:15) is characterised by several colours, which indicates the change in value of the initial R, G, B components. Component L, on the margin of the position, has rounded, gradient values.
8. The complete colour gamut of image WA is rendered in figures 34 and 35. The spread of colours is dependent upon the representation space, figure 36, the LAB space being the most uniform.
9. The multitude of colours in image WA, figure 37, is accounted for by border (outline) pixels – figure 38, adjacent transition pixels, mapping pixels – figure 39 and by accidental (isolated) pixels.
10. In recreating image WK similar to image WA, one starts from the R, G and B values in table II. Each colour position (1:15) is replaced with the new values to obtain figure WK in Matlab, figure 40, with values ranging between 0 and 1, standard form, for each of the three chromatic components, figure 41. Figure WK is pure in colour terms, with a clear-cut distinction between the colour position (1:15) and the white background, figure 41. Sequence II leads to image WK with the .jpeg extensions (one of the available options), corresponding to figure WK, with the properties listed in figure 42. Image WK.jpg includes the pixels marked in the 0:255 interval, figure 43. In image WK the border and adjacent pixels are identified.
10. The comparative analysis of images WA, WD and WK is outlined in figures 44 – 49, with WK serving as benchmark for the comparison. Differences from image WK are insignificant, i.e. the R, G, B values in the two images (WA and WD) are close.
11. Correction using MOPM results in changes to the R, G, B values.
12. The colours that form figure WK, 15 in total, are present in figures 50, 51 and in locus CIE xy and CIE upvp of figures 16 and 17. In conclusion, in order to perform a comparative analysis of scientific data the use of background pixels is recommended.

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