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# Colour Luminance Contrast of Digital Projection Image

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## Introduction

In these later years extensive changes in presentation technologies occurred. High-powered digital projectors, efficient screens were developed; programs for creating the presentations were vastly simplified. It all enabled applying modern methods of transmitting information not only in business, but also in scientific and teaching remits.

On the other, presentations are hold in enlightened rooms. Ambient light or backlight degrades luminance contrast and visibility of the image in the same breath. Ambient light discolours image, therefore its colour gamut narrows. Colour contrast decreases as well.

The concept *colour contrast* (the contrast between two colours) is used often but it is not specifically academically defined yet. Generally we can say that the highest contrast (difference) is between diametrically opposite factors. Thus the highest contrast should be obtained between two colours, which are directly opposite each other on Munsell's colour wheel. These are the colours positioned at 180° from each other [1].

The maximum contrast between light and dark is obviously between black and white. However, the contrast between blue and yellow is also very high.

Human eye responds to luminance, therefore the visibility of colours should be analysed as their luminance contrast.

### Notation of colour luminance contrast

General formula of the luminance contrast is as follows:

$$K = \frac{|L_f - L_b|}{L_b}, \tag{1}$$

where $K$ – luminance contrast; $L_f$ – foreground luminance; $L_b$ – background luminance.

On analysing the colours, coordinate $Y$ can be used. It is equivalent to luminance in the XYZ colour system [2–4]. Thus Eq. (1) could be modified to obtain the formula of colour luminance contrast:

$$K_c = \frac{|Y_n - Y_W|}{Y_n + Y_W + Y_a}, \tag{2}$$

where $K_c$ – colour luminance contrast; $Y_n$ – coordinate $Y$ of „$n$“ colour; $Y_W$ – coordinate $Y$ of white colour; $Y_a$ – coordinate $Y$ of ambient light.

Ambient light is evaluated as a part of projector‘s luminance white constituent and is signified as a factor $k$:

$$Y_a = kY_W. \tag{3}$$

The values of factor $k$ vary from $k$ = 0 (no ambient light, the room is absolutely obscured) to $k$ = 1 (luminance created by ambient light equals to luminance of white light created by projector), ranging from 0,1 to 0,7 in practice.

Eventual equation of colour luminance contrast:

$$K_c = \frac{|Y_n - Y_W|}{Y_n + (1+k)Y_W}. \tag{4}$$

Colour luminance contrast was computed.

The most often used for backgrounds five pure computer colours were chosen as follows: White – W = R255 + G255 + B255; Black – K = R0 + G0 + B0; Dark Red (brown) – R80; Dark Green – G80; Dark Blue – B80.

The other pure computer colours were chosen as foregrounds: Red – R255; Green – G255; Blue – B255; Cyan – C = G255 + B255; Magenta – M = R255 + B255; Yellow – Y = R255 + G255; White – W = R255 + G255 + B255; Black – K = R0 + G0 + B0.

All computing results are shown in Table 1. It should be noted that the colour difference remains the same when ambient light is added, but contrast decreases notably, therefore visibility deteriorates.

Some consistent patterns can be noticed (Fig. 1–4). First of all, colour luminance contrast obviously decreases as constituent of ambient light increases. Secondly, in regard to every background there are several inherent colours, which have high colour luminance contrast and ambient light has lower influence on them. Colour luminance contrast of such colours decreases less than 50 % when factor of ambient light $k$ is less than or equal to 0,7. These colours could be called as „lightproof“.

**Table 1**. Results of colours' luminance contrast computing

| Colour of foreground | Constituent of ambient light (factor *k*) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **0** | **0,05** | **0,1** | **0,2** | **0,3** | **0,4** | **0,5** | **0,7** | **1,0** |
| **White background (W =** R255 + G255 + B255) | | | | | | | | | |
| R = R255 + G0 + B0 | 0,65 | 0,62 | 0,60 | 0,56 | 0,52 | 0,49 | 0,46 | 0,41 | 0,36 |
| G = R0 + G255 + B0 | 0,17 | 0,16 | 0,16 | 0,15 | 0,14 | 0,13 | 0,13 | 0,12 | 0,10 |
| B = R0 + G0 + B255 | 0,87 | 0,83 | 0,79 | 0,73 | 0,68 | 0,63 | 0,59 | 0,52 | 0,45 |
| C = R0 + G255 + B255 | 0,12 | 0,12 | 0,11 | 0,11 | 0,10 | 0,10 | 0,09 | 0,09 | 0,08 |
| M = R255 + G0 + B255 | 0,56 | 0,54 | 0,52 | 0,48 | 0,45 | 0,42 | 0,40 | 0,36 | 0,31 |
| Y = R255 + G255 + B0 | 0,04 | 0,04 | 0,04 | 0,03 | 0,03 | 0,03 | 0,03 | 0,03 | 0,02 |
| K = R0 + G0 + B0 | 0,98 | 0,93 | 0,89 | 0,82 | 0,76 | 0,70 | 0,66 | 0,58 | 0,49 |
| **Black background (K =** R0 + G0 + B0) | | | | | | | | | |
| W = R255 + G25 + B255 | 0,98 | 0,93 | 0,89 | 0,82 | 0,76 | 0,70 | 0,66 | 0,58 | 0,49 |
| R = R255 + G0 + B0 | 0,91 | 0,74 | 0,63 | 0,48 | 0,39 | 0,33 | 0,28 | 0,22 | 0,17 |
| G = R0 + G255 + B0 | 0,97 | 0,91 | 0,85 | 0,76 | 0,69 | 0,63 | 0,58 | 0,49 | 0,41 |
| B = R0 + G0 + B255 | 0,76 | 0,47 | 0,34 | 0,22 | 0,16 | 0,13 | 0,11 | 0,08 | 0,06 |
| C = R0 + G255 + B255 | 0,97 | 0,92 | 0,87 | 0,78 | 0,71 | 0,65 | 0,60 | 0,52 | 0,43 |
| M = R255 + G0 + B255 | 0,93 | 0,80 | 0,70 | 0,56 | 0,46 | 0,40 | 0,35 | 0,28 | 0,21 |
| Y = R255 + G255 + B0 | 0,98 | 0,93 | 0,88 | 0,81 | 0,74 | 0,69 | 0,64 | 0,56 | 0,47 |
| **R80 background (R80 =** R80 + G0 + B0) | | | | | | | | | |
| W = R255 + G25 + B255 | 0,98 | 0,93 | 0,89 | 0,82 | 0,75 | 0,70 | 0,65 | 0,58 | 0,49 |
| R = R255 + G0 + B0 | 0,90 | 0,73 | 0,62 | 0,47 | 0,38 | 0,32 | 0,28 | 0,22 | 0,16 |
| G = R0 + G255 + B0 | 0,97 | 0,91 | 0,85 | 0,76 | 0,69 | 0,62 | 0,57 | 0,49 | 0,41 |
| B = R0 + G0 + B255 | 0,72 | 0,45 | 0,33 | 0,21 | 0,16 | 0,13 | 0,10 | 0,08 | 0,06 |
| C = R0 + G255 + B255 | 0,97 | 0,91 | 0,86 | 0,78 | 0,71 | 0,65 | 0,60 | 0,52 | 0,43 |
| M = R255 + G0 + B255 | 0,92 | 0,79 | 0,69 | 0,55 | 0,46 | 0,39 | 0,34 | 0,27 | 0,21 |
| Y = R255 + G255 + B0 | 0,98 | 0,93 | 0,88 | 0,80 | 0,74 | 0,68 | 0,64 | 0,56 | 0,47 |
| K = R0 + G0 + B0 | 0,08 | 0,02 | 0,01 | 0,01 | 0,01 | 0,00 | 0,00 | 0,00 | 0,00 |
| **G80 background (G80 =** R0 + G80 + B0) | | | | | | | | | |
| W = R255 + G25 + B255 | 0,92 | 0,88 | 0,84 | 0,78 | 0,72 | 0,67 | 0,62 | 0,55 | 0,47 |
| R = R255 + G0 + B0 | 0,69 | 0,57 | 0,49 | 0,38 | 0,31 | 0,27 | 0,23 | 0,18 | 0,14 |
| G = R0 + G255 + B0 | 0,90 | 0,84 | 0,79 | 0,71 | 0,64 | 0,59 | 0,54 | 0,46 | 0,39 |
| B = R0 + G0 + B255 | 0,29 | 0,20 | 0,16 | 0,11 | 0,08 | 0,06 | 0,05 | 0,04 | 0,03 |
| C = R0 + G255 + B255 | 0,90 | 0,85 | 0,81 | 0,73 | 0,66 | 0,61 | 0,56 | 0,49 | 0,41 |
| M = R255 + G0 + B255 | 0,76 | 0,66 | 0,58 | 0,47 | 0,39 | 0,34 | 0,30 | 0,24 | 0,19 |
| Y = R255 + G255 + B0 | 0,92 | 0,87 | 0,83 | 0,76 | 0,70 | 0,65 | 0,61 | 0,53 | 0,45 |
| K = R0 + G0 + B0 | 0,60 | 0,30 | 0,20 | 0,12 | 0,08 | 0,07 | 0,05 | 0,04 | 0,03 |
| **B80 background** (B80 = R0 + G0 + B80) | | | | | | | | | |
| W = R255 + G25 + B255 | 0,99 | 0,94 | 0,90 | 0,83 | 0,76 | 0,71 | 0,66 | 0,58 | 0,50 |
| R = R255 + G0 + B0 | 0,96 | 0,78 | 0,66 | 0,50 | 0,40 | 0,34 | 0,29 | 0,23 | 0,17 |
| G = R0 + G255 + B0 | 0,99 | 0,92 | 0,87 | 0,77 | 0,70 | 0,64 | 0,58 | 0,50 | 0,41 |
| B = R0 + G0 + B255 | 0,90 | 0,54 | 0,39 | 0,25 | 0,18 | 0,14 | 0,12 | 0,09 | 0,06 |
| C = R0 + G255 + B255 | 0,99 | 0,93 | 0,88 | 0,79 | 0,72 | 0,66 | 0,61 | 0,53 | 0,44 |
| M = R255 + G0 + B255 | 0,97 | 0,83 | 0,72 | 0,57 | 0,48 | 0,41 | 0,36 | 0,28 | 0,22 |
| Y = R255 + G255 + B0 | 0,99 | 0,94 | 0,90 | 0,82 | 0,75 | 0,69 | 0,65 | 0,57 | 0,48 |
| K = R0 + G0 + B0 | 0,43 | 0,09 | 0,05 | 0,03 | 0,02 | 0,01 | 0,01 | 0,01 | 0,01 |

### Colour luminance contrast of the positive image

The positive image has a dark foreground and a light background.

Elaborating results of research shows that the least number of lightproof colours there is on White background (see Fig. 1). There are Black and Blue foreground objects which are well seen only. These colours are well-chosen for objects with a small angular dimension (text, thin lines, small figures).

Colour luminance contrast of even such bright colours as Red and Magenta varies from 0,45 to 0,60. Thus these colours can be considered as moderate lightproof colours. They can be successfully used for colour objects with bigger radial dimension (large-scale title fonts, middle-sized figures and their outlines, thicker than usually used lines).

Colour luminance contrast of the rest colours is less than 0,2; therefore they can be used like filling of sizeable objects.

After exploring light backgrounds such as Yellow or Cyan we can see that computing results are identical to White background ones.

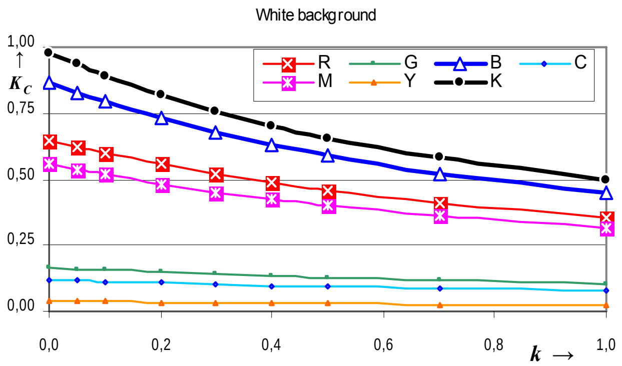


**Fig. 1.** Colour luminance contrast reliance on constituent of ambient light in the case of image with White background

### Colour luminance contrast of the negative image

The negative image has a light foreground and a dark background. It is important that there are more lightproof colours in case of use negative image slides.

Analysis of foreground colours on the Black background shows (see Fig. 2) that there are four lightproof colours: White, Yellow, Cyan, and Green. Luminance of these

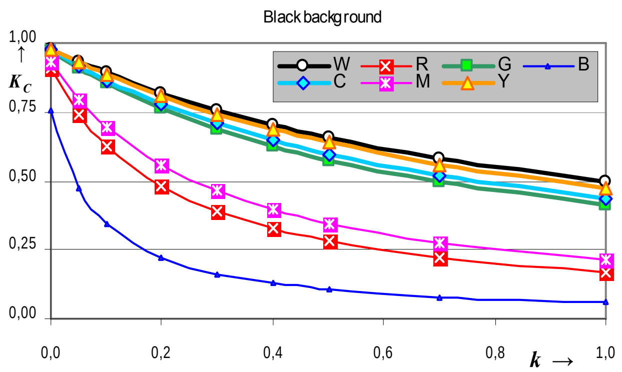


**Fig. 2.** Colour luminance contrast reliance on constituent of ambient light in the case of image with Black background

colours decreases in half when factor of ambient light $k$ is less than or equal to 0,7 ($k \leq 0{,}7$). In this case possible options of well seen colour for object with a small angular dimension are twice as many as in positive image.

Even Red and Magenta foregrounds are slightly more lightproof compared to slides of positive image, therefore possibility of applying these colours increases while using projectors with more intense luminous flux.

It is not always necessary to use only Black background. Some other dark background colours can be chosen. Analogous results were get on Dark Red (R80 + G0 + B0), Dark Green (R0 + G80 + B0), and Dark Blue (R0 + G0 + B80) backgrounds (see Fig. 3–5). In all cases the same 4 colours remain lightproof: White, Yellow, Cyan, and Green. Red and Magenta can be applied additionally.

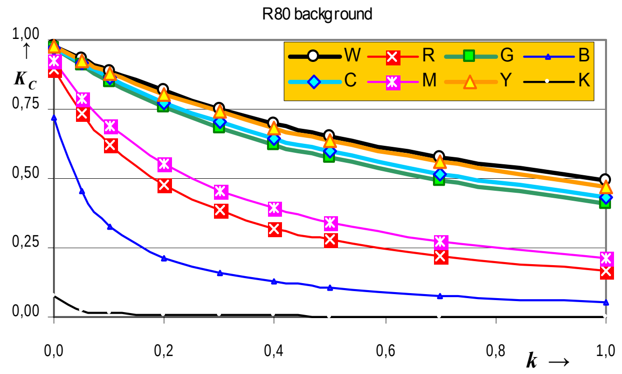


**Fig. 3**. Colour luminance contrast reliance on constituent of ambient light in R80 background

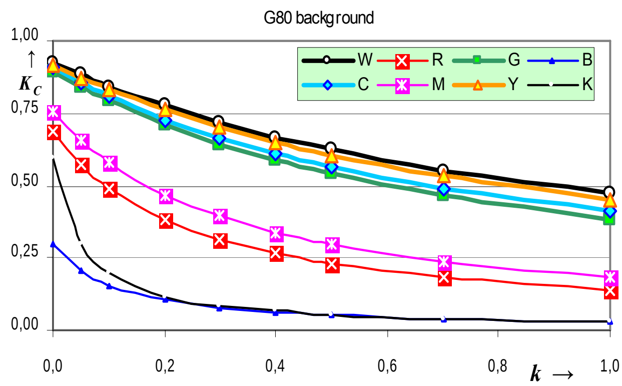


**Fig. 4**. Colour luminance contrast reliance on constituent of ambient light in the case of image with G80 background

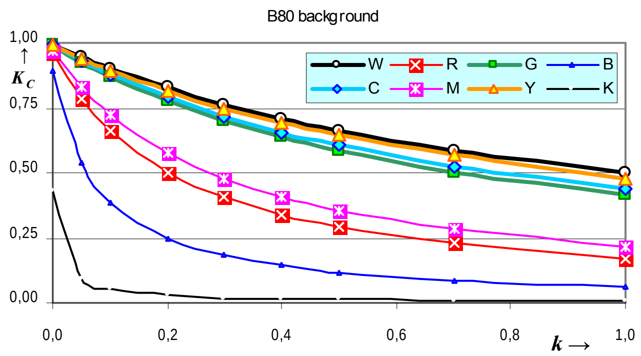


**Fig. 5**. Colour luminance contrast reliance on constituent of ambient light in the case of image with B80 background

### Other positive features of negative image

Image area from a screen projects into the eye and its projection area on the retina corresponds the one of the object which has a relatively large solid angular dimension. In the case of a negative image, human eye adapts to a low luminance, therefore it becomes more sensitive and the small image details are seen well. Because of the same reason eye becomes more sensitive to colour luminance contrast.

Small light details of negative image seems as though are bigger, lines visually seems to be thicker because of the irradiation effect, so the visibility of the image gets better.

### Conclusions

1. High colour luminance contrast can be got on dark backgrounds as follows: Black, Dark Red (brown), Dark Green and Dark Blue. The highest colour luminance contrast is received when the foreground is White or has the one of these pure colours – Yellow, Cyan, and Green. Furthermore the influence of ambient light over these colours is the least.
2. High colour luminance contrast of positive image can be got with Black and Blue colours as foreground only. It is very low when the foreground is Green, Cyan or Yellow, therefore these colours can be used for large objects entirely.
3. Colour luminance contrast of Red and Magenta foreground are lower in both negative and positive images, therefore these colours should be used for colouring sizeable objects.

### References


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Several factors determine visibility of a presentation in an enlightened room. One of them is colour luminance contrast. Colour luminance contrast reliance on ambient light was explored. On the base of results, foreground and background colour combinations of the best screen-image visibility were determined. The highest colour luminance contrasts can be got in the case of dark background and the foreground of White, Yellow, Cyan or Green colour. Ambient light has the least influence on these colours. The highest colour luminance contrast on White background is with Black and Blue foregrounds only; in the case of Green, Cyan and Yellow foreground colour luminance contrast is low, so these colours should be used only for large objects. Colour luminance contrast of Red and Magenta is low of both negative and positive images; therefore these colours are well-chosen for sizeable objects. Ill. 5, bibl. 4 (in Lithuanian; summaries in English, Russian and Lithuanian).



**С. Масёкас, М. Крюглайте, К. Отас. Контраст яркости цвета изображения в цифровой проекции // Электроника и электротехника. – Каунас: Технология, 2007. – № 7(79). – С. 19–22.**

Видимость изображения презентации в освещенном помещении предопределяется несколькими факторами. Исследована зависимость одного из них – контраста яркости цвета – от освещенности помещения. На основе расчетов определены цвета объектов и фонов, создающие наилучшие сочетания по видимости. Наибольший контраст яркости цвета и наименьшее влияние освещенности помещения наблюдались в случае белого, желтого, голубого и зеленого объектов на черном фоне. На белом фоне наибольшим контрастом яркости цвета обладают лишь черные и синие объекты; контраст яркости зеленого, голубого и желтого цветов является незначительным, поэтому эти цвета следует использовать лишь для наиболее крупных объектов. Контраст яркости цвета красных и пурпурных объектов является небольшим как на негативном, так и на позитивном изображениях, поэтому эти цвета применимы для объектов средней величины. Ил. 5, библ. 4 (на литовском языке; рефераты на английском, русском и литовском яз.).



**S. Masiokas, M. Kriuglaitė, K. Otas. Skaitmeninės projekcijos vaizdo spalvų skaisčio kontrastas // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2007. – Nr. 7(79). – P. 19–22.**

Pateikties vaizdo matomumą apšviestoje patalpoje lemia keli veiksniai. Ištirta vieno iš jų – spalvų skaisčio kontrasto – priklausomybė nuo patalpos apšvietimo. Apskaičiavus nustatyta, kurie fono ir objekto grynų spalvų deriniai sudaro geriausią vaizdo matomumą. Spalvų skaisčio kontrastas didžiausias ir patalpos apšvietimo įtaka mažiausia, kai baltas, geltonas, žydras arba žalias objektas projektuojamas tamsiame fone. Baltame fone didžiausią spalvos skaisčio kontrastą sudaro tik juodi ir mėlyni objektai; žalios, žydros ir geltonos spalvų skaisčio kontrastai labai maži, todėl rodytini tik labai dideli šių spalvų objektai. Tiek pozityvinio, tiek negatyvinio vaizdo raudonos ir purpurinės spalvų objekto skaisčio kontrastas yra palyginti nedidelis, todėl rodytini vidutinių matmenų šių spalvų objektai. Il. 5, bibl. 4 (lietuvių kalba; santraukos anglų, rusų ir lietuvių k.).