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Influence of Chromatic Ambient Light over Colour Luminance Contrast on Projection Screen

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Introduction

Digital image projection on screen became leading way of information visualization. As it entrenched, projection technique started improving eminently rapidly and has reached the peak today. However, even with usage of powerful digital projectors with mighty luminous flux, influence of ambient light can not be avoided. We can not avoid ambient light unreservedly, but it‘s possible to reduce its impact and reach possibly best image on screen.

Poor visibility on screen is probably the biggest problem of major part of all presentations. Visibility depends on visual angle, luminance contrast and colour luminance contrast. The latter is especially influenced by ambient light, which discolours image and reduces contrast. While creating a presentation it is necessary to consider influence of ambient light and to use colour combinations of highest luminance contrast.

The same ambient light influences various colours differently, so least ambient light sensitive colours can be identified. When environmental situation and influence of ambient light over different colours is known, fading of the image can be reduced and better visibility obtained.

Formerly influence of white ambient light over colour luminance contrast was analysed [1], but it is none the less important to explore influence of chromatic ambient light.

Contrasts

One of the most important visibility factors is luminance contrast, but there are few luminance contrast concepts and application of each is specific.

Weber contrast C_W is ratio of task and background luminance difference and background luminance.

$$C_W = L_t – L_b / L_b, \tag{1}$$

where L_t – task luminance; L_b – background luminance.

In this case negative contrast (black text on white background) or positive contrast (black text on white background) commonly used in presentations is possitive. Range of negative contrast is $-1 \leq C_W \leq 0$, positive contrast ranges from 1 to infinity. Results of visual task differs for every case, though not so much that such wide range of variation could be used. For more convenient comparison modified formula of Weber contrast is used. Luminance difference in numerator is compared to highest luminance value $L_{\max}$. At that rate range of contrast is $0 \leq C_W \leq 1$. Suchlike specified concept is espacially usable when background luminance and luminance of adaptation field L_a is different. It‘s common situation when presentation is held in enlighted room and eye adopts to luminance of surroundings, which depends on reflectance and illuminance of the walls, meanwhile image in slide is displayd in dark background.

Michelson contrast C_M was derived for periodic structures, where is no dominant colour (background), which determines observer‘s luminous adaptation (Fig.3)

$$C_M = (L_{\max} – L_{\min}) / (L_{\max} + L_{\min}) . \tag{2}$$

Critical luminance is estimated as space-avarage luminance.

Luminance ratio C_R is ratio of the highest and lowest luminance values and is used to describe features of electronic devices, mostly dispalys [2]. Maximum range of change of black and white image pixels is usually described by this contrast

$$C_R = L_W : L_B = L^*_{\max}:1 , \tag{3}$$

where L_W and L_B – luminance of white and black image.

Instead of luminance of white image relational highest luminance $L^*_{\max}$ given in relational units is used compared to black image luminance of which is equated to 1. As an additional information luminance of white computer display is given in cd/m^2. Ratio between target and background luminance or its logarithm is used.

$$\log C_R = \log L_W – \log L_B . \tag{4}$$

Luminance ratio can only be applied for simple graphics with uniform background [2].

Colour difference and Colour luminance contrast

Above-mentioned luminance contrasts are used for characterizing black-and-white image. Consept of colour contrast is not clearly defined in literature. Usually there are only qualitative descriptions, which designate colour contrast as an assessment of the difference of appearance of two simultaneously seen colours [3]. Quantative definition is under the influence of lots of optical illusions and factors, impacting colour perception [4]. In Munsell colour wheel colours being directly opposite each other, i. e. distant 180°, are held as most contrasted. Though such contrast is quite psychological. Another version is to describe colour contrast as a property by which two colours of equal luminance but different chromaticity can be distinguished from each other [5]. For the present the most specific definition is overthreshold difference defined as a minimal difference of colour perception thresholds [6].

Namely minimal difference is mentioned, as you may go from one colour over to another not neccesarily in shortcut. Because of uneveness of colour space the distance, having the least number of thresholds, not neccesarily is the shortest, and otherwise.

Colour difference is distance between two colour vectors in uniform colour space

$$\Delta \mathbf{E} = \mathbf{C}_1 - \mathbf{C}_2 . \qquad (5)$$

This difference is usually presented as colour contrast in literature.

Vector of any colour on screen may be shown as a sum of two vectors (Fig 1.)

$$\mathbf{C} = \mathbf{C}_p + \mathbf{C}_{W0} , \qquad (6)$$

where $\mathbf{C}_p$ – vector of any projector‘s colour; $\mathbf{C}_{W0}$ – vector of white ambient light .

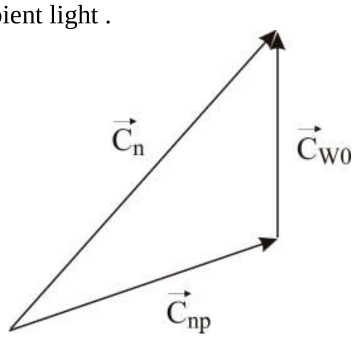

Fig. 1. Colour vector shown as as sum of two vectors

Vector of colour difference between two colours $\Delta\mathbf{E}$:

$$\Delta \mathbf{E} = \mathbf{C}_W - \mathbf{C} = \mathbf{C}_{Wp} + \mathbf{C}_{W0} - \mathbf{C}_p - \mathbf{C}_{W0} , \qquad (7)$$

$$\Delta \mathbf{E} = \mathbf{C}_{Wp} - \mathbf{C}_p , \qquad (8)$$

where $\mathbf{C}_{Wp}$ – vector of White projector‘s light.

When ambient light appears, its vector ($\mathbf{C}_{W0}$) is added to vectors of two colours ($\mathbf{C}_{Wp}$; $\mathbf{C}_p$). New derived vector of colour difference ΔE deflects in parallel, though its numerical value remains the same (Fig. 2). Ambient light adulterates colours, therefore visibility deteriorates. Thus colour difference between two primal and faded colours remains the same.

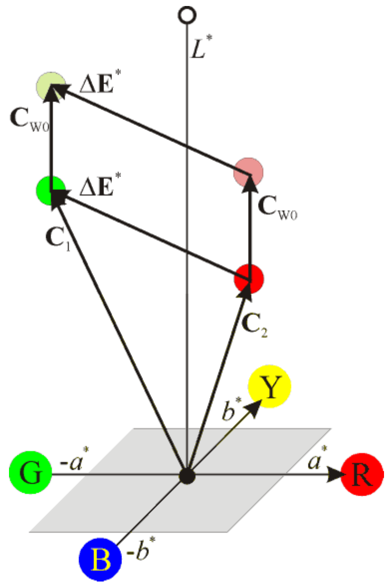

Fig. 2. Vector of colour difference with and without white ambient ligh.

There is a suggestion to add on another criterion – colour difference ΔE, and call contrastic two colours, which have big colour difference and big luminance difference [7].

In research of ambient light influence over visibility criterion of colour difference is insufficient. Consepts of colour difference and colour contrast shoul not be equalized.

Concept of **Colour luminance contrast** was first introduced in previous paper. [1]. This concept may be held as the closest to Weber contrast and results may be compared to results of black-and-white image contrast.

In colour luminance contrast calculation Y coordinate is used, which corresponds to luminance in XYZ colour system. Maximal luminance (L = 100 %) equals to 683 cd/m^2 [6].

$$C_c = (Y_t - Y_b)/(Y_t + Y_b + k\, Y_0) , \qquad (9)$$

where C_c – colour luminance contrast; Y_t – Y coordinate of task colour; Y_b – Y coordinate of background colour; Y_0 – Y coordinate of ambient light; k – constituent of ambient light.

Range of ambient light and its substantiation

The best visibility on screen can be achieved when there is no ambient light. It is practically impossible totally insulate from ambient light, and not even necessary, as it is common to screen presentations in enlighted room. With regard to visibility, presence of ambient light is not most important. The bottom line is its ratio to main light source – projector.

Permissible ratio of ambient and main light source luminous flux is 1:4. Thus illuminance of screen created by projector should be four times bigger than illuminance of surroundings. Seeing that this ration in practise is usually exceeded, range of ambient light with double reserve – up to 0,5, was analysed. At this rate illuminance of screen created by projector is twice bigger than illuminance created by surroundings.

Results and analysis

White W (R255, G255, B255) and Black K (R0, G0, B0) backgrounds were used in research. These task colours were chosen: White W (R255, G255, B255), Black K (R0, G0, B0), Red R (R255, G0, B0), Green G (R0, G255, B0), Blue B (R0, G0, B255), Cyan C (R0, G255, B255), Magenta M (R255, G0, B255) and Yellow Y (R255, G255, B0). Ambient light of the same colours was analysed except for Black.

Influence of every colour ambient light over every colour object in White and Black backgrounds was explored. Objects which had primary luminance contras with no ambient light lower than 0,7, were eliminated as too ambient light sensitive and not analysed.

R, G, C, M, Y objects are not usable in White background and only B and K tasks are practicable. Black object in White background is the most suitable one (Fig. 3). With no ambient light luminance contrast hits the highest value – 1. Even when constituent of ambient light is 0,25 luminance contrast for all ambient light colours is greater or equals to 0,8. Black object is marginally sensitive for Blue, Red and Magenta ambient light. In these cases luminance contrast remains greater than 0,8 and exceeds 0,9 in Blue ambient light when its constituent attains 0,5 value.

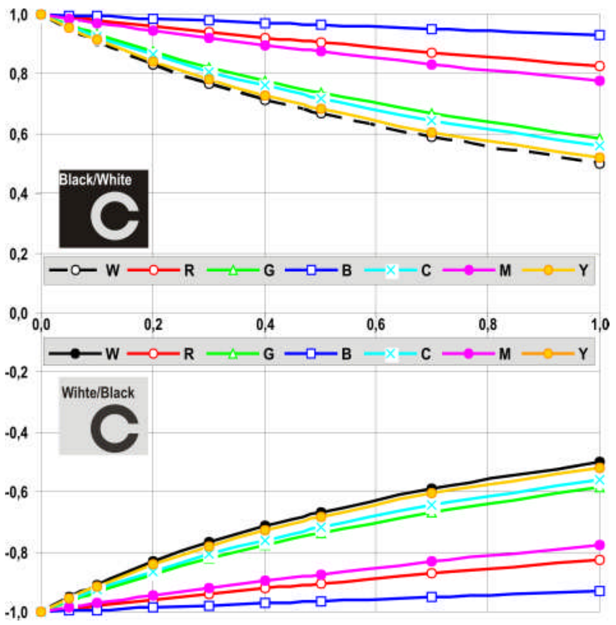

Fig. 3. Influence of different colour ambient light over colour luminance contrast for White task on Black background and Black task on White background

Blue object is also faintly sensitive to Blue, Red and Magenta ambient light (Fig. 4), though as constituent of ambient light reaches 0,25 only these three mentioned reache the boundary of luminance contrast 0,8.

There are four proper task colours for Black background: G, C, Y and W. Results of C with G and W with Y are practically identical (Fig. 3-6). All four objects are most sensitive to White and Yellow ambient light and least sensitive for Blue, Red and Magenta ambient light. In case of ambient light constituent 0,5 luminance contrast of Yellow and White objects exceeds 0,6 for all colours af ambient light. Luminance contrast of all objects exceeds 0,8 value only for Blue, Red and Magenta ambient light.

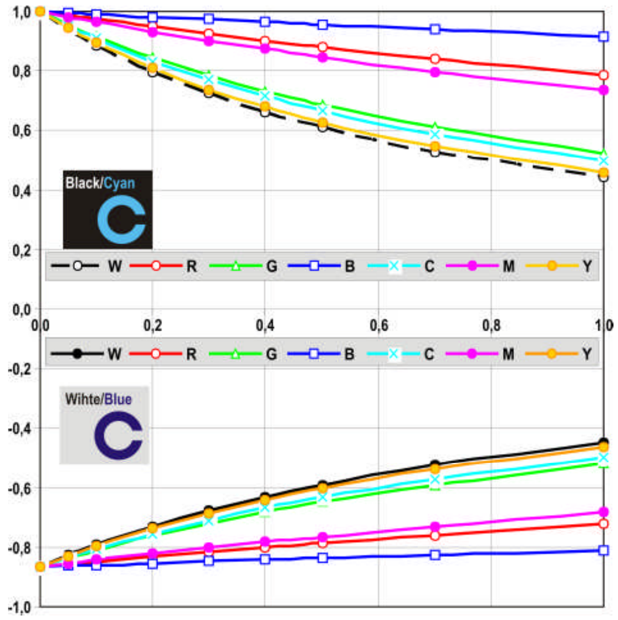

Fig. 4. Influence of different colour ambient light over colour luminance contrast for Cyan task on Black background and Blue task on White background

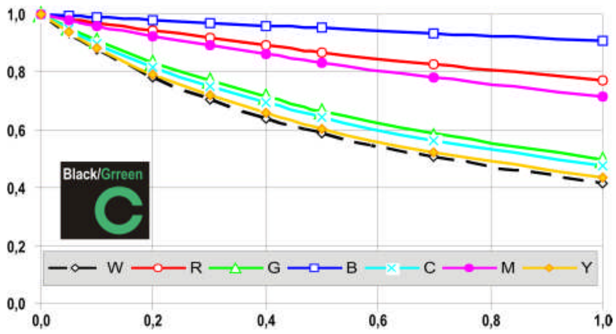

Fig. 5. Influence of different colour ambient light over colour luminance contrast for Green task on Black background

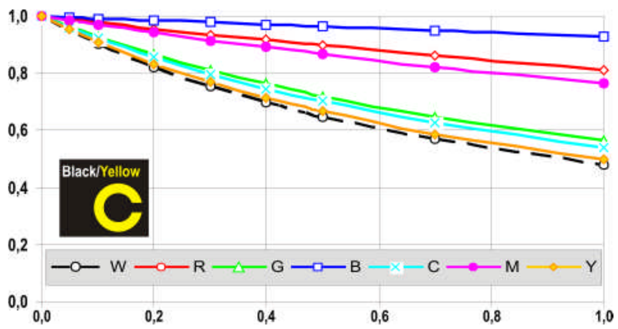

Fig. 6. Influence of different colour ambient light over colour luminance contrast for Yellow task on Black background

Practical rekomendations

With reference to results of analysis, practical recomendations for creating a presentation can be formulated.

There are more usable task colours in Black background than it is in White. So Black or other low luminance backgrounds should be used instead of habitual White. Uniform and plain backgrounds are the best. Any pictures or textures distracts observer and tires vision. As colour reproduction depends on every device it is best to use primal colours. There should not be more than 7 different colours in one slide. In area of peripheral vision White target will be better noticed.

Conclusions

1. There are two usable task colours for White background – Black and Blue, while Black background has twice as many – Green, Cyan, Yellow and White.
2. All the task colours are most sensitive to White and Yellow ambient light, least sensitive to Blue, Red and Magenta ambient light. Luminance contrast in Blue ambient light in all cases exceeds 0,8 when constituent of ambient light is 0,5.

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Digital image projection on screen is the main way of information visualization entrenched in science, teaching and business areas. And though technique and equipment for visualization has probably reached the peak today, visibility on screen is influenced by ambient light. It is impossible avoid ambient light, but its influence can be reduced by using least ambient light sensitive colour combinations. Analysis of influence of chromatic ambient light over colour luminance contrast for different task and beckground colours, showed that there are Black and Blue usable tasks in White background and White, Green, Cyan and Yellow tasks for Black background. Tasks of any colour is most sensitive to White and Yellow ambient light and least sensitive to Blue, Red and Magenta ambient light. Ill. 6, bibl. 7 (in English; summaries in English, Russian and Lithuanian).

С. Масёкас, М. Крюглайте. Влияние цветного постароннего света на контраст яркости цвета на проекционном экране // Электроника и электротехника. – Каунас: Технология, 2009. – № 5(93). – С. 69–72.

Цифровое проектирование изображения на екран стало главным способом визуализации в кругах деятелей науки, обучения и промысла. Хотя проекционная техника наверно достигла вершины, видимостъ изображения ухудшает посторонний свет. Полностъю избежатъ постороннего света невозможно, но можно уменьшить его влияние, подбирая наилучшие сочетания менъше всего цветочувствителъных цветов. После исследования как цветной посторонний свет влияет на контраст яркости цвета между объектами и фонами различных цветов выяснилось, что на белом фоне наибольшим контрастом яркости цвета обладают черный и синий объекты, на чёрном – белый, зелёный, голубой и жёлтый объекты. Объекты всех цветов болъше всего чувствителъны белому и жёлтому постороннему свету, менъше всего – синиму, красному и пурпурному постороннему свету. Ил. 6, библ. 7 (на английском языке; рефераты на английском, русском и литовском яз.).

S. Masiokas, M. Kriuglaitė. Spalvotos pašalinės šviesos įtaka spalvų skaisčio kontrastui ekrane // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2009. – Nr. 5(93). – P. 69–72.

Skaitmeninis vaizdo projektavimas ekrane šiandien yra pagrindinis informacijos vizualizavimo būdas, įsigalėjęs mokslo, mokymo, verslo srityse. Nors projekcinė technika yra pasiekusi bene aukščiausią tašką, vaizdo matomumą ekrane blogina pašalinė šviesa. Visiškai išvengti pašalinės šviesos neįmanoma, bet galima sumažinti jos įtaką pasirenkant mažiausiai pašalinei šviesai jautrių spalvų derinius. Ištyrus, kokią įtaką spalvota pašalinė šviesa turi skirtingų spalvų objektų ir fonų skaisčio kontrastui, buvo nustatyta, kad baltame fone tinkami yra juodas ir mėlynas objektai, juodame fone – baltas, žalias, žydras ir geltonas. Visų spalvų objektai jautriausi baltai ir geltonai pašalinei šviesai, mažiausiai jautrūs – mėlynai, raudonai ir purpurinei. Il. 6, bibl. 7 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).