COLOR MANAGEMENT TECHNIQUES AND COLOR RENDERING IN THE VISUAL COMMUNICATION DESIGN

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Abstract: The present paper focuses on the means and techniques of color management and the ways in which they can render in a qualitative manner the products of the visual communication design. It aims to clarify problems related to the printing and presenting of realistic digital images, which are the main element of every design composition. A number of colormetric spaces have been presented with a focus on those that do not depend on the device of color rendering. The paper analyzes the specifics of color perception of the human eye, which start with its very structure, continue through the optic nerve and reach deep inside the brain. Color is a sensation caused in the eyes and the brain by various lengths of the waves, or by energy as photons to which man reacts through the perception of color. The visual sensation of color is due to the elimination or reduction of some wavelenthgs of visible light. Thus, the object absorbs all colors with the exception of the color a person sees. The predominant color of the observed object is exactly the opposite to the color absorbed by the object. The reproduction of the colors by a person is performed in the eye ball comprising three coats and innermost nucleus, and the inner, light sensitive one is called retina. It contains the light sensitive cells (photoreceptors): rods – receptors for light and dark and flasks or cones – three types of receptors for color vision. Each of them is responsible for the red, green or blue color. In search of analogous connection with software developed for color management we have analyzed various mdels of human vision, which form the basis of color management. We have demonstrated the connection between three-component color perception in humans and color rendering in the design of means of visual communication, in whose images again three basic colors are used: cyan, magenta, yellow in printed ones and red, green, blue in digital ones. The paper presents also data from the research of the “metamerism“ phenomenon where the colors, which look the same in one light source are not perceived as same with another source of light. It can be explained with the difference in the spectral composition of the different sources of light and respectively the differences in the extent to which wavelengths are absorbed or reflected by the lit object. CIELAB colormetric space is presented as a universal, device- independent method of measuring the quality of color rendering and color management.

Keywords: color, color management, color rendering, metamerism, CIELAB color space

1. INTRODUCTION

Vision is the most important sense of the human being. It accounts for 85 – 90% of the information received through the senses. With the ***visual system*** we perceive light, recognize the shape of objects and living organisms, determine their movements, and differentiate between colors. The information we have obtained is processed in the visual cortex (a scaled image of the zones in the cortex, in particular the visual zone colored in pink, can be seen in Fig. 1).

The visual analytical mechanism consists of the organ of vision or the eye, the optic nerve and the parts of the brain to which the visual information is transmitted and where it is processed. The eye is made up of the eye ball and additional (ancillary) organs. The eye ball consists of three coats and inner nucleus, and the innermost, light sensitive coat of the eye ball is called retina. It contains the light sensitive cells (photoreceptors): rods – receptors for light and dark and flasks or cones – receptors for color vision, responsible for the red, green and blue colors (Fig. 2) [1].

In order to see objects they need to be lit. Rays of light reach the eye, pass through the deflecting media and get to the retina. From the various dots on the object, the shafts of light gather on the retina, as a result of which we get a reduced and upturned image of the object. The excitation in the light sensitive receptors of the retina is transmitted to the optic nerve and reaches the visual area of the cortex where the visual sensation and perception of the object take place. There the two real, reduced but upturned images are laid one over the other.

It has been established that vision in a dark environment is due to the rods, and in good light to the flasks. At a low intensity of light the eye has maximum sensitivity to the shortest wavelengths. With daytime and night time vision the maximums are within ***the green*** and ***yellow*** spectral area. If the lighting of the environment is reduced even further, the green color will be brighter. This state is known as **“the Purkinje phenomenon”** and with such lighting of the environment green objects become brighter than the yellow and red ones [2].

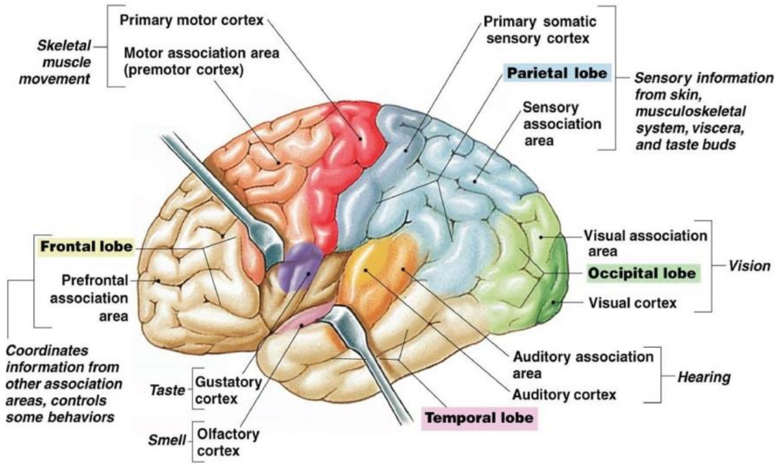

Fig. 1. Areas in the cortex

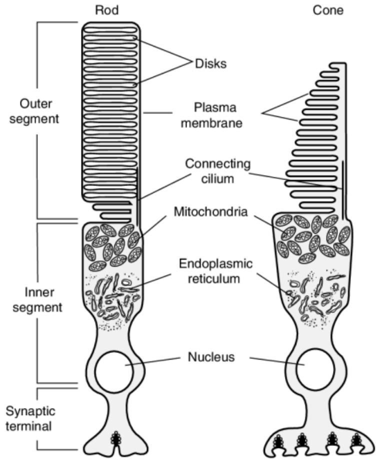

Fig. 2. Rod's and Cone's structure

This complexity of the visual mechanism, in combination with good lighting of the spatial environment allows the consumer of the visual communication design to register various “color agitators“ and to react accordingly depending on the physiological, psycho-emotional, optical, and symbolic-associative impact of the coloring of a particular product design [1].

In order to have effective visual communication, however, it is necessary for the particular product design to have a high quality of color rendering. It is particularly important for printed design items with which the durability of the colors, when transferring them from the original digital form into a realistic color sample, is a factor that determines the motivation of consumers to come to a decision to make a purchase (or to use a particular service).

In search of the right method with high level of color rendering in product design, we can make a connection between human color perception (“Three-component color vision“), and color rendering in digital (RGB color space) and printed (CMYK color space) images. Color perception of humans, as well as color rendering in design is due to three types of pigment structures - light sensitive cells (flasks) or the use of three basic colors.

In section 2 we have presented the specifics of device-dependent and device-independent color rendering models. Knowing them is an essential factor for the right color rendering of a design and respectively for achieving the impact on the consumer we seek.

2. COLOR SPACES IN THE VISUAL COMMUNICATION DESIGN

2.1. Device - dependent color rendering models

The main device-dependent color rendering models used in visual communication design are:

RGB color space: this space is connected to the additive synthesis of the three basic colors: Red, Green and Blue. With a zero intensity of the three color beams we get black color on the screen with maximum intensity of the three beams we get white color. Combinations of different intensity of the three beams can generate the whole color space of the light specter visible to the human eye. Additive mixing is used in the picture tubes of television sets and monitors, and partially in photography (Fig. 3).

CMYK color space: like additive color mixing, the subtractive one also consists of three basic colors in different concentration – blue-green (Cyan), cyclamen (Magenta) and Yellow out of which we can get a wide specter of derivative colors. Zero concentration of the three basic colors produces a white color, and their maximum concentration – a black color. For the needs of polygraphy a fourth basic but neutral color has been added – black. Thus comes into being the CMYK color model, which is often used in full color printing (Fig. 3).

Derivative color spaces: CMYKOG - color model HexaChrome (Pantone), which is based on 6 basic colors: CMYK, orange (Hexachrome Orange) and green (Hexachrome Green).

Those color spaces are called “device-dependent color rendering“as the resultant color is a set of RGB or CMYK digits with different manifestation in different devices or on different types of paper where they are observed.

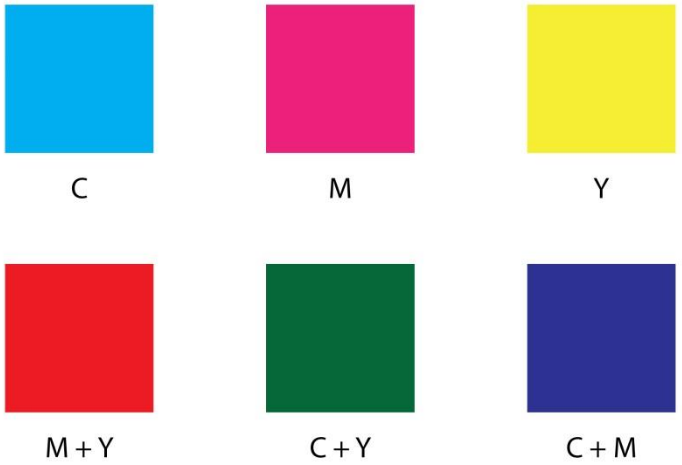

Fig. 3. The colors of CMYK (without Black -”K”) and RGB color spaces

Due to the specifics of color rendering it is necessary for the digits corresponding to a particular color, to be transmitted to each device. This contributes to high resistance and objectivity of representing the color palette in a particular product design. In spite of that there is the possibility for subjective color perception and respectively, for lack of satisfaction of consumers needs and expectations.

Color management systems allow to solve the problem related to the subjectivity of color spaces by assigning absolute color meanings to RGB and CMYK digits. Color management makes it possible to determine the real color meaning of the RGB or CMYK set of digits, and also to reproduce color from another device by changing the digits, which are sent to it. But in order to do that color management has to rely on a different type of numerical color model based on **human perception**, and not on the colorants of the device.

2.2. **Device - independent color rendering models**

Color models, which are device-independent are based on the information provided by the CIE commission (International Commission on Illumination), which is concerned with the establishment of standards for all aspects of light, including color. CIE developed a mathematical model of color CLE XYZ (1931), which demonstrates what color perception is of people of normal vision and under specific conditions of observation [3].

It is necessary to understand the difference between device-dependent color models such as RGB and CMYK, and device-independent models such as CIE XYZ and CIELAB.

CIE color model: the most widely used CIE color model is CIELAB. It uses three primary axes: L * a * b *, where L* is the axis illustrating the lightness of the color with the darkest value (black color) with L * = 0 and the lightest one (white color) with L * = 100. Color channels a * and b * present neutral grey values with a * = 0 and b * = 0. Axis a * represents the colored tone from red (at a positive + a * value) to green (at a negative - a *value), and axis b * represents the colored tone from blue (at a negative - b * value) to yellow (at a positive + b *value). Combinations of red /green and blue/yellow are opponent and contrasting colors, which mutually exclude each other. The size and the limitations of the a * and b * axes depend on the specific performance of the assigned color, but they are often within the range of -128 to +127.

CIELAB color space (Fig. 4) can be accepted as universal language of color rendering among various kinds of devices. The colors are defined irrespective of the nature of their creation or the device on which they are shown. CIELAB color space is three-dimensional real numerical space, which by definition comprises an infinite number of possible presentations of the colors. It has been designed to provide universal color rendering and makes it possible to control the color when it passes from one device to another through a correlation of its specific RGB or CMYK values in perceptually based L * a * b * ones. Space is usually depicted as three-dimensional whole number for digital representation, irrespective of the device, and for these reasons values L *, a * and b * are usually absolute, with a previously determined range, [3].

CIELAB color space covers a bigger range than that of the RGB and CMYK color models (for example, ProPhoto RGB includes around 90% of all perceived colors).

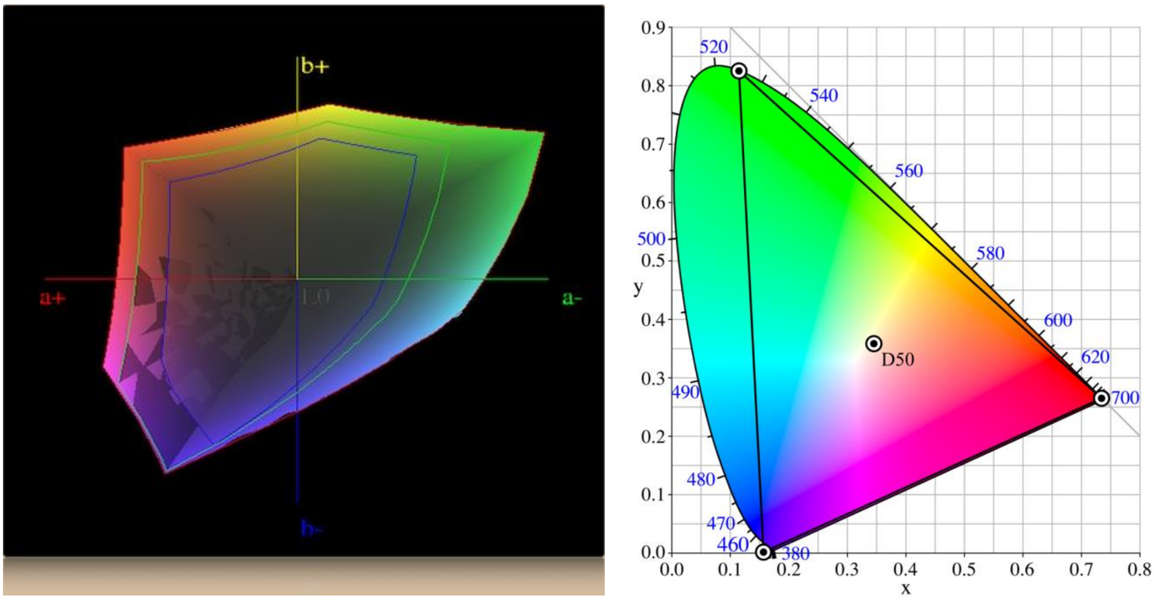

Fig. 4. CIELAB color space

CIELAB color space does not define absolute colors unless the white dot is specified. Often in practice the white dot is accepted to follow a standard and is not exactly specified (for example, for "absolute colorimetric" rendering intend, L * a * b * values of the International Color Consortium are relative to standard lighter D50 of CIE), [4].

3. COLOR MANAGEMENT SYSTEMS

Due to the vast number of possible implementations of input and output devices it is necessary to use color management systems, which facilitate their precise rendering in the digital original versions and realistic printed color samples used by designers.

Color management systems (CMS) should be capable of performing two important tasks:

- They must figure out which particular colors human vision perceives at specified RGR and CMYK values;
- They must maintain these colors in their gradual transfer from device to device.

In order to accurately perform these tasks it is necessary that the designer sets realistic colors to be rendered, taking into consideration the existing limitations to color management systems.

The main functioning of color management systems is relatively simple and comprises two basic things: they render specific color meaning to RGB or CMYK digits, which unambiguously represents a specific color; change RGB or CMYK values from the monitor on which they have been created to the different devices of color rendering (monitor, ink-jet printer, offset press, etc.) so that each of them reproduces the same colors.

One of the solutions is the introduction of intermediate representation of the desired colors, called Profile Connection Space or PCS. The role of PCS is to serve as a centre for all transformations from device to device, where mlinks are the input devices to PCS, and nlinks are from PCS to the different output devices (Fig. 5).

Each link effectively describes the behavior of color rendering of the device. This link is called profile of
the device. The profiles of the devices and PCS are two of the four basic components in all color management systems.

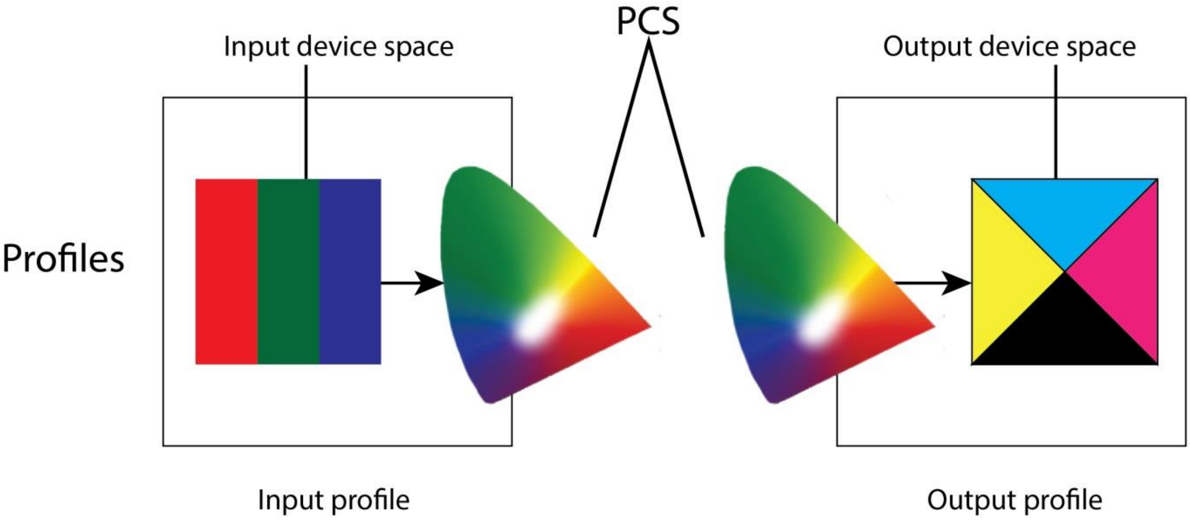

Fig. 5. Profile Connection Space

3.1. Components of color management systems:

All ICC (International Color Consortium) based systems for color management use the following basic components, [3]:

- **PCS (Profile Connection Space)** – the intermediate linking space makes it possible to present an unambiguous color digital value in CIE XYZ or CIELAB, which does not depend on the specifics of the different devices, which are used to render that color. PCS is the measure used for measuring and determining the color. ICC specification uses two different spaces - CIEXYZ and CIELAB, as PCS for the different type of profiles. The key characteristic of CIEXYZ and CIELAB is that they represent the perceived colors. This allows color management systems to use CIE XYZ and CIE LAB as a "hub" through which all color transformations pass. When a certain color is defined by XYZ or LAB values, this will provide correct information about the way in which consumers with normal color vision will see them;
- **Profiles** - describes the connection between RGR or CMYK control signals and the real color these signals generate and also determines the values CIEXYZ or CIELAB, which correspond to the set of RGB or CMYK digits. The profile can describe only one device, for example, a scanner, monitor or printer, class devices, such as displays of Apple Cinema, Epson Stylus Photo 1280 or SWOP printers, or abstract color space like Adobe RGB (19981 or CIELAB). The profile contains a set of recordings with values of the control signal of the device (RGB or CMYK digits) and another set presenting the real colors expressed in PCS. The profile gives the quantity to the RGB or CMYK values. It does not by itself change the digits of RGB or CMYK in reality but informs that they represent that specific color (defined in XYZ or IAB). Similarly, the profile does not change the behavior of the device – it simply describes that behavior. It is important to know the difference between **calibration**, which changes the behavior of the device and **profiling**, which describes it. The conversion of colors always requires two profiles - source and destination. The profile of the source shows to CMS the real colors, which the design contains, and the profile of the destination shows to the CMS what control signals it is required to reproduce. It can be assumed that the profile of the source tells the CMS where the color comes from, and the profile of the destination informs where it will be reproduced;
- **CMM (Color Management Module)** – part of the software, which carries out all calculations needed to convert RGB or CMYK values. CMM works with the color data contained in the profiles. As the profiles cannot contain PCS definitions for all possible RGB or CMYK combinations, CMM calculates their interim values. CMM provides color management systems with a method of transforming the color values of the source to the PCS and from PCS to all destinations of color rendering. The specifics of CMM can be found out in the transformation of white to a "scum dot", where 1 % of the ink of one or more color channels replace white paper. Moving to a different CMM often solves that problem. The differences in the interpolation can vary from fine to vast;
- **Rendering intents** - each device has a fixed range of colors, which it can reproduce as dictated by the laws of physics. Monitors cannot reproduce a deeper red color that the one produced by the red phosphorus in the device. The range of colors, which the device can reproduce is called color gamut. The ICC specification includes four ways of rendering intents, which stand for various methods of dealing with “out-of-gamut colors”, which are located in the space of the source and which due to the incapability of the output device to reproduce have to be replaced by others. Rendering intents make it possible to indicate where to take

the replacement colors from. **Perceptual and saturation renderings** use compressive gamut, discoloring all colors from the space of the source so that they will fit in the gamut of the destination. **Relative and absolute colorimetric renderings** transform all out-of-gamut colors to the closest reproducible color tone.

3.2. Calibration of the monitor as a condition for correct color rendering

Calibration means correcting the behavior of the device so that it produces specific, already known response to the stimuli (always to produce the same color in response to a certain set of digits). That process ensures:

- **Stability** - profiling is a lot more successful when the output device is stable, i.e. a certain stimulus will always provoke one and the same response (a set of RGB of CMYK digits). When the reaction of the device changes with time, the profile gradually becomes less precise replacing the values of the color from the sought ones;
- **Optimization (Linearization)** – after the device achieves stability an optimization is needed that will use the largest possible dynamic range and color gamut of transfer;
- **Simulation** – it is necessary to make a simulation on another device, for example, when adjusting the monitor to correspond to the brightness of the white paper.

These three steps sometimes compete so it is possible to have to choose between stability and dynamic range. In most cases the stability of the output device is a priority.

4. CONCLUSION

The present study presents various techniques of color management, the ways for right color rendering and their impact on the quality of sustainable reproduction in visual communication design. The paper proves the importance of knowing them, as they are the main instrument by means of which designers can identify possible color displacements at the level of conceptual idea. In that way a higher efficiency of visual communication is achieved, which impacts consumer demand and the motivation for taking a decision to make a purchase. We have analyzed the key relation between the ways of color rendering at the consumer - observer, as well as the digital original and the realistic printing sample of the product. We come to the conclusion that the equal number of basic perceived number of colors by man and a machine managing the rendering of the color, provides an opportunity for its correct measurement and reproduction.

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