An overview about monitors colors rendering

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Abstract: **-** The goal of this paper is to study how different TV technologies work, and to compare them. We analyze three different situations: a CRT monitor, a LCD monitor and a LEDs monitor. Using the different monitors' spectral power distributions, we propose a six steps spectral image processing algorithm which converts the spectral image in to XYZ standard and then in to the RGB standard. Finally we colour balance the RGB image in order to eliminate the monitors unwanted render colours hues. On the monitors displays we expect to see the same colours text image. Also we present the monitor's colours properties like: colours saturation, brightness, contrast and sharp.

Key-Words: - spectral image, CRT, LCD, LED monitors, monitors spectral power distribution, render image colors properties.

1 Introduction

In recent years multimedia technologies gained a lot of popularity, and during these years has appeared different new TV technologies. The most important characteristic of a TV is the colors rendering. A display device is an output device for presentation of information for visual and additive perception, which was transmitted in various forms. When the input information is supplied as an electrical signal, the display is called electronic display [19]. A monitor display is a piece of electrical equipment which displays images generated by devices such as computers, without producing a permanent record. The monitor comprises the display device, circuitry, and an enclosure. The display device in modern monitors is typically a thin film transistor liquid crystal display (TFT-LCD), while older monitors use a cathode ray tube (CRT). More general the display technologies can be characterized as: emissive (CRT, gas plasma), Transsmitive (Liquid Crystal Displays (LCD), Liquid Crystal on Silicon (LCOS)) and Reflective Displays (Digital Light Processing (DLP), Organic Led Displays (OLED)) [6, 19].

In this paper our goal is to analyze from each category of display technology a representative TV display and to make a comparison between monitors' colors rendering possibilities. We analyze the CRT, the LCD and the LEDs monitors. In order to do that we use an illumination algorithm in which we use as input data the displays' spectral power distribution. In function of the monitor spectral power distribution, for the color checker input text image, we obtain the brut monitor colors render for each monitor. In order to obtain the final monitor render image we make the color balance. We expect to see on each monitor the same input colors image without any color differences.

After the TV or the monitor is tested, peoples use to watch television or to work on computers and they appreciate the quality parameters of the colors render images like: luminosity, colors saturation, contrast, brightness and sharpness [2,4-6,10,11,14]. We image simulate the colors render image properties, that can be easily modified using a remote control or the adjustments buttons form TV and computer monitors.

2 The monitors colors rendering

Color vision is the capacity of an organism or machine to distinguish objects based on the wavelengths of the light they reflect or emit. Color derives from the spectrum of light (in our case the display light emission) interacting in the eye with the spectral sensitivities of the light receptors. The nervous system derives color by comparing the responses to light from the three types of cone photoreceptors in the eye L, M, S (long, medium and short) equivalent to R, G, B (red, green and blue) colors [9-12,18]. Reflected color can be measured using a reflectometer, which takes measurements in the visible region of a given color sample. If the custom of taking readings at 3.7 nanometer increments is followed, the visible light range of 400-700nm will yield 81 readings [13]. These readings are typically used to draw the sample's spectral reflectance curve. The color checker spectral image is defined as a 496X256X81. In order to render colors on a display we use an algorithm that convert the spectral image in to XYZ standard, and then in to the RGB standard in function of each monitor spectral power distribution [3,6,18]. Each monitor has a different spectral power distribution consequently we expect to have on each display the same image with different colors hues. Finally we make the white balance in order to perceive a more realistic colors image. The white balance is the process of removing unrealistic color casts, so that objects which appear white in person view are rendered white on the display image.

Human vision is sensitive to visible light, that part of the electromagnetic spectrum with wavelengths from about 400 to 700 nm. Complementary displays render colors images in the visible wavelength band, in order to be perceived by human eyes. In our analysis color rendering means the ability of display or monitor to show true colors as they are seen outdoors in sunlight (or indoor under different bulbs illumination) by the normal human eyes.

Our system consists of a spectral image [13] which is used as the text image (the color checker image), and the CRT, the LCD and the LEDs monitors which render the illuminate image. We see the color checker text image on the monitors' screens. The monitors have different spectral power distributions [3,6,12,15] and in function of these we see the text image having different hues. In order to eliminate the image colors hues, we color balance the image.

2.1 The spectral image processing algorithm

In this paper we use a spectral image under the Spectral Binary File Format (.spb). This format has the following characteristics: file identifier is a 3 letter string SPB (Spectral Binary file) located at the beginning of the file. Image dimensions and wavelength values are stored in file header. Dimensions (x, y and n) are stored in uint32 format and wavelength values in foat32 format. Spectral image values are reflectance values stored as float32. Spectral image values are scaled between 0 and 1, where 1 describes maximum reflectance. Image data is written to the file in column order and values are stored in little endian form [13].

If we perceive light that is reflected from a surface, instead of light that is directly emitted from a light source, our eyes receive result of the scalar product of reflectance and radiance spectrum. In continuous case human eye response is:

$$c_i = \int_{\lambda \min}^{\lambda \max} S_i(\lambda) r(\lambda) l(\lambda) d\lambda \qquad i = S, L, M \qquad (1)$$

$S_i(\lambda)$ is the function of sensitivity of the i-th type of cones,

$r(\lambda)$ is the fraction of the reflected illuminant energy,

$l(\lambda)$ is the spectral distribution of light,

L, M, and S are the responses of the long, medium, and short cones of the eye [9-12,14-18].

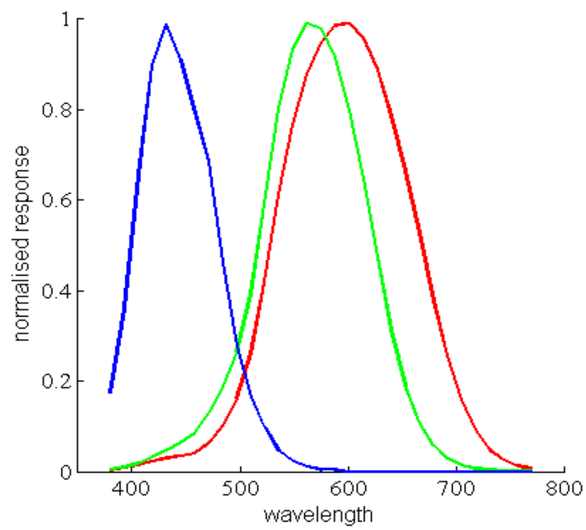


Fig. 1 the normalized L, M, S cones

In 1931 CIE decided to propose a particular set of color matching functions as a standard. These functions are denoted as $x(\lambda)$, $y(\lambda)$, $z(\lambda)$ (Fig. 2). The color-matching functions are defined to match the eye's sensitivity to brightness. According to equation(1) the corresponding tristimulus values X, Y, Z for stimuli f are:

$$\begin{aligned} X &= k\sum_{\lambda} x(\lambda) f(\lambda) \Delta\lambda \\ Y &= k\sum_{\lambda} y(\lambda) f(\lambda) \Delta\lambda \\ Z &= k\sum_{\lambda} z(\lambda) f(\lambda) \Delta\lambda \end{aligned} \qquad (2)$$

k is the normalization factor.

The relation between r, g, b and x, y, z:

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} 0.412 & 0.357 & 0.180 \\ 0.212 & 0.715 & 0.072 \\ 0.01 & 0.11 & 0.95 \end{bmatrix} \cdot \begin{bmatrix} r \\ g \\ b \end{bmatrix}. \qquad (3)$$

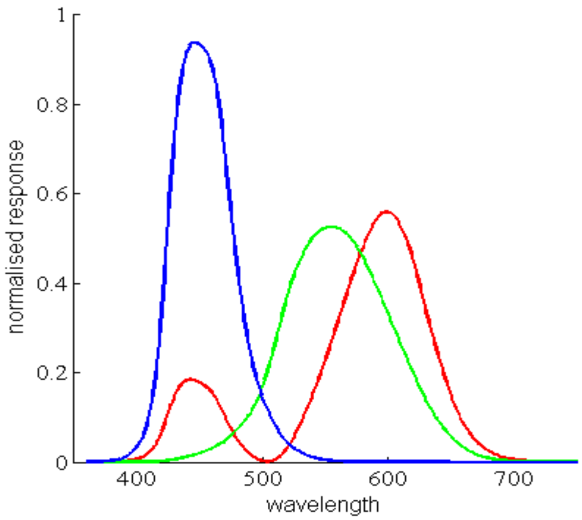


Fig. 2 CIE 1931 XYZ primary stimuli

The ITU-R BT.709 standard specifically describes the encoding transfer function for a video camera that when viewed on a standard monitor 3)will produce excellent image quality. The implicit target of this encoding is a standard video monitor whose transfer function or CRT gamma is not explicitly delineated. Instead a typical monitor setup is assumed. This recommendation specifies the encoding of real world scene tristimulus values into a standard monitor RGB color space assuming a dark viewing condition [11,14,15]. A common choice of primaries for a display device is the recommended standard 709 RGB primaries:

$$M_{709} = \begin{bmatrix} 0.640 & 0.330 & 0.030 \\ 0.300 & 0.600 & 0.100 \\ 0.150 & 0.060 & 0.790 \end{bmatrix}. \qquad (4)$$

A white point is a set of tristimulus values or chromatic coordinates that serve to define the color white in image capture, encoding, or reproduction. A commonly used white point is D_{65} white point:

$$x_{D65} = 0{,}3127;\ y_{D65} = 0{,}3290;\ z_{D65} = 0{,}3582. \qquad (5)$$

Gamma is the exponent on the input of the monitor that distorts it to make it darker. Since the input is normalized to be between 0 and 1, a positive exponent will make the output lower. The NTSC standard specifies a gamma of 2.2. By definition [2,11,12] gamma is a nonlinear operation used to code and decode luminance or tristimulus values in video or image systems. Gamma correction is, in the simplest cases, defined by the following power law expression:

$$V_{out} = V_{in}^{\gamma}. \qquad (6)$$

At decompression the gamma values for NTSC standard is 0.45.

Luminance is a measure of radiant light energy that is based upon the non-linear human visual response (logarithmic) to light. This is because the human eye easily responds to specimens having low-amplitude, dim features in the same view field with bright highlights, but linear imaging devices are incapable of correctly reproducing the differences in luminance and extremes in dynamic range, generated by these specimens. Exponential functions more closely match the logarithmic response of the human eye.

2.1.1 The steps of the colors rendering algorithm

In conformity with the equations(1:6) we have the next spectral image processing algorithm [14,15]:

1) Load the data into Matlab (spectral image and monitors' spectral power distribution).
2) For each monitor' spectral power distribution, we compute the human eye color response using equation(1).
   We use the tristimulus values in XYZ for each pixel by applying the color matching functions CIE 1931.
4) We use the transformation matrix M to convert from XYZ coordinates to the 709 RGB primaries with a D65 white point.
5) We convert from the XYZ standard into the RGB standard.
6) The gamma correction.

2.2 The colors balancing

Color balancing belongs to a class of digital image enhancement algorithms that are useful for correcting color casts in captured images. In our cases, unusual overall color casts (or uniform discolorations) typically result from different monitors' spectral power distribution. In our algorithm the colors balance adjustment is often necessary in order to produce acceptable color quality in digital images. The human eye is designed to readily adapt to changing illumination conditions in order to identify a white object as white even when the surrounding intensity and colors temperature fluctuate. In contrast, monitors displays require careful scrutiny and adjustment of the red, green, and blue signal amplitudes in order to produce similar results [4,6,14,15].

The process of color balancing includes trying to determine what the illuminant of a particular scene (display) is and then adjusting the intensities of the red, green, and blue channel of the image, in order to recover the original color characteristics of the scene. Since for most images, we can not accurately determine the scene illuminant, we considered a Mean and Standard Deviation algorithm [4, 14]. We noticed that many of the images seem to be lacking in contrast, making them appear hazy. They also appeared to be quite dark in color, an indication of low mean channel values. Therefore, in addition to adjusting the standard deviation values we adjust the mean of each channel as well. To compensate for these shortcomings in the original image, we adjust the mean of each channel to be 0.5, and we also set the standard deviation of each to be roughly 0.27 (or 70 on a 256 value scale).

3 The display overview

Image rendering electronic displays can be divided into projective displays and reflective displays. Projective displays can be of two types emissive and transsmitive. Emissive displays are those in which the image-forming element also serves as the source of light, while transsmitive displays modulate some aspect of an extrinsic illumination source. There are currently a large number of display technologies for rendering electronic images; the cathode ray tube (CRT) is the dominant emissive technology while the liquid crystal display (LCD) is the pervasive transsmitive technology. Also, nowadays they are light emitting diodes (LEDs) screens which represent the reflective displays [6-8,19]. The purpose of the display characterization is to specify the relationship between the values that control the input into the display and the light emitted by the display. The output is characterized by the monitors' SPD and the input by the monitors' frame buffers.

In our paper each display is characterized by its own spectral power distribution. The spectral power distribution of a display represents the power radiated by the screen at the various wavelengths of the visible spectrum. In order to see how the monitors render colored text image, we use the monitors' spectrums as input data in our spectral image processing algorithm. The spectral power distribution of each of the individual channel adds linearly when combinations of the color channels are turned on. We compare the SPD of the white channel at specific channel color values with the sum of the SPD of the individual R, G, and B channels at the same channel color values. The results in (Fig. 3,5,7) show that there is very little discrepancy between the SPD of combinations of different channel color values to the corresponding sum of the SPD of the individual color values [12].

The primary roles of the frame buffer are the storage, conditioning, and output of the video signals that drive the display device. Gamma (equation 6) gives the relationship between the frame buffer values and the intensity of the display primaries. Each type of monitor has its own gamma function, which has a very different shape in comparison with the other monitors gamma functions.

3.1 The CRT monitor's operating principle

In a CRT monitor an electron beam hits a phosphor screen exciting it to emit a visible photon. Video input voltages are applied to each electron gun assembly, which includes control grids for modulating the beam current flowing from the cathodes as well as electrodes to accelerate, shape and focus the electron beams on the phosphor-coated faceplate. The electrons that pass through the shadow-mask apertures excite the R, G, and B phosphors. The phosphors absorb electrons which cause the light emission in a process called cathodoluminescence [5-8,19]. In Fig. 3 we see the SPD of the primary phosphor emissions in a CRT monitor. The red phosphor SPD has several discrete spikes. Such spikes are not commonly found in nature, and consequently the CRT emissions almost never match the spectral power distribution found in the original scene. The color match can only be arranged basing on the eye's inability to distinguish between different spectral power distributions that generate colors images (metamerism) [6,12,15].

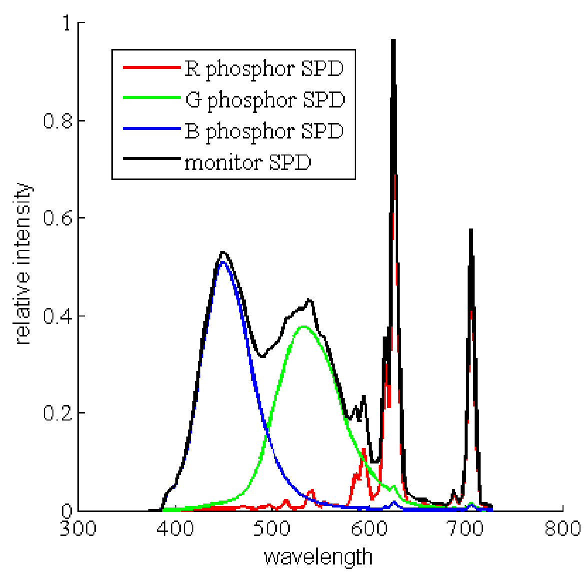


Fig. 3 the normalized SPD of a CRT monitor

In Fig. 4 we have the gamma function of a CRT monitor. The gamma function is nonlinear. The value of the exponent differs between the displays, but is generally between 1.7 and 2.2. The purpose of the gamma function is to increase the luminosity of the render image, and is a correction done by the monitor's hardware [6,12,14-19].

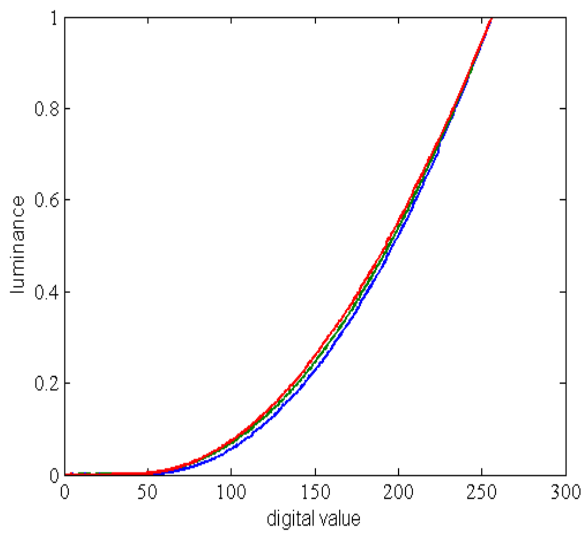


Fig. 4 the gamma function of a CRT monitor

The perceived brightness of a digital image render by a display is dependent of the display's spectral power distribution. This affects the intensity distribution and interrelationship of contrast between light and dark regions in the specimen. Phosphors of monitors do not react linearly with the intensity of the electron beam. Instead, the input value is effectively raised to an exponent called gamma.

3.2 The LCD monitor's operating principle

A thin film transistor liquid crystal display (TFT-LCD) is one type of active matrix LCD. It is composed of a backlight illumination source, diffuser, rear linear polarizer, glass sheets with transparent thin-film indium-tin-oxide electrodes and thin-film transistors, optically active layer of birefringent liquid crystal material, absorbing thin-film color selection filters, and a front polarizer. Farther information about LCD functionality can be found in [1,6-8,19].

The LCD backlight illumination is generate either by a hot-cathode or a cold-cathode fluorescent lamp. The fluorescent lamp has a high luminous efficiency and the ability to tailor the SPD of the lamp via the selection and mixture of individual phosphor components and their proportional contributions to the total phosphor blend. Tri-band phosphor mixtures are typically employed to improve color performance for these lamps. The final emission spectra are the weighted sum of the three phosphor emissions plus energy at the mercury emission lines (fluorescent lamp spectrum) [6,12,15].

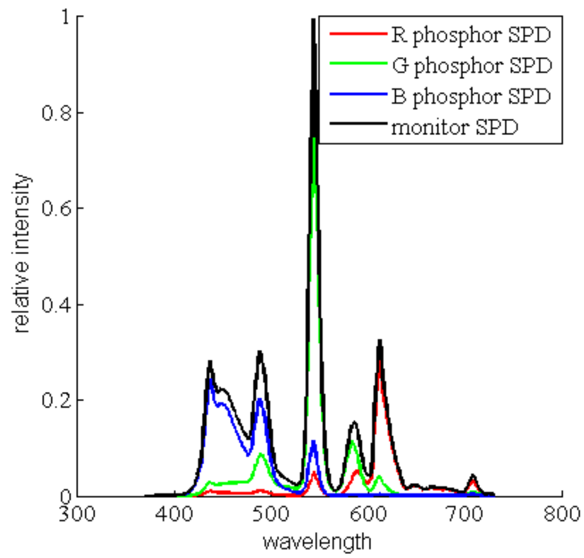


Fig. 5 the normalized SPD of a LCD monitor

In Fig. 4 we see the SPD of a LCD monitor. The three primaries SPD in a LCD display vary considerably. The spikes distributions are due to the materials placed in the fluorescent backlights. The peaks of the backlight emissions are designed to fall at the centers of the pass bands of the thin-film color filters that are part of the LCD assembly. The shapes of the blue and green primary SPDs are narrower than the corresponding distributions for the CRT. This results in a larger range of displayable colors.

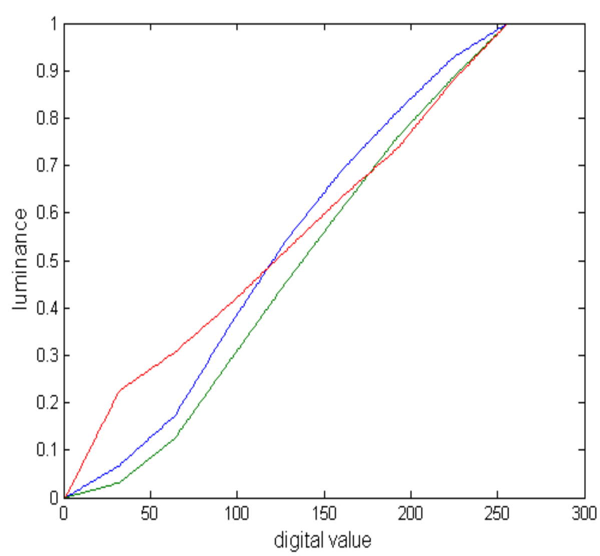


Fig. 6 the gamma function of a LCD monitor

The relation between the digital frame buffer value and the light intensity is nonlinear, as for the CRT. The value of the gamma exponent is about 2.6. In function of the LCD monitor construction, the gamma shape was arranged by the manufacturer in order to have approximately the same effect as the CRT monitor's, gamma has. This constructive solution was chosen in order not to have differences in the colors render by the monitors, when a normal eyes viewer watch on the CRT and LCD TVs the same picture in the same time [6,11,12].

3.1 The LEDs monitor's operating principle

LEDs can be used as the backlight of the LCD displays, due to the advantages of their being mercury free, of high color gamut and having a long lifetime and fast response, compared with the conventional LCD mercury lamps backlights. LEDs have a much lower driving voltage (<5 V) which is more suitable for mobile monitors and TV applications in the driving-circuit design and safety issues. Due to the fast response of the LEDs, it is very easy to switch the LEDs backlight on and off, to insert the black frames, to eliminate motion blur behaviors specific to the LCD, due to their impulse type characteristics [8,19].

LEDs have a suitable and narrow emission spectrum to fit the liquid crystal and color filter and the luminance uniformity over the whole panel. Red, green and blue LEDs can be driven individually which makes it possible to light different colors in series to achieve a filter less LCD with high transmission and colors saturation. For small LCD displays (such as mobile phones), color gamut is not a main issue. Hence, white LEDs can be enough as the backlight source to reduce the cost and minimize the module size. For medium or large size LCDs, multicolor LEDs are needed in order to increase the power efficiency and color gamut [8,19]. For these applications, the FWHM (full width at half maximum) of the LEDs should be as small as possible to increase the color gamut value. Optical characteristics of LEDs change due to the ambient temperature and operation during time.

LED monitors use white LEDs for the backlight, which allows for a slimmer profile, longer life, and less power consumption. We use side-emitting white LEDs. The LED has a color spectrum with a typical color temperature of 5500K with a minimum and maximum value lying between 4500K and 10000K. Using a lens arrangement above the die, most of the flux is directed to the sides instead of the normal lambertian distribution. This is ideal for the large screen displays as mentioned above. There are two primary ways of producing high intensity white light using LEDs. One is to use individual LEDs that emit the colors red, green, blue and then to mix all the colors in order to produce white light. The other is to use a phosphor material to convert monochromatic light from a blue or UV LED to broad-spectrum white light, much in the same way a fluorescent light bulb works [8,19].

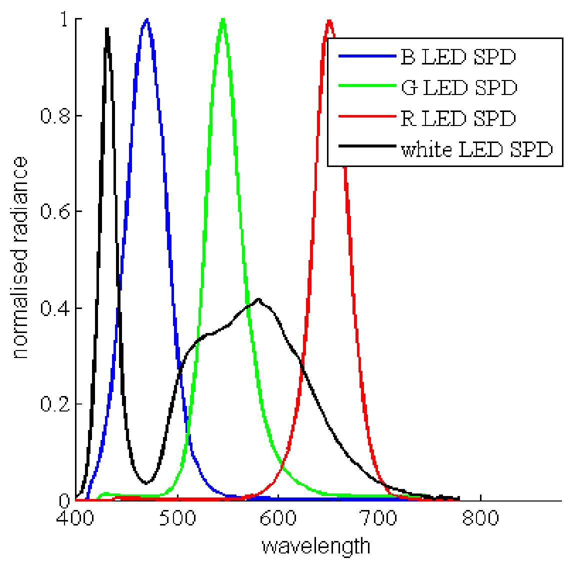


Fig. 7 the normalized SPD of a LEDs monitor

In Fig. 7 we see the spectrum of a white LED and the spectrums of the red, green and blue LEDs. For the white LED, the graphic clearly show blue light with a peak at about 465 nm and a broadband light emitted by phosphor which emits at roughly 500–700 nm. The spectrum of the blue, green and red LEDs cover a band centered on 490nm, 550nm and 640nm [3].

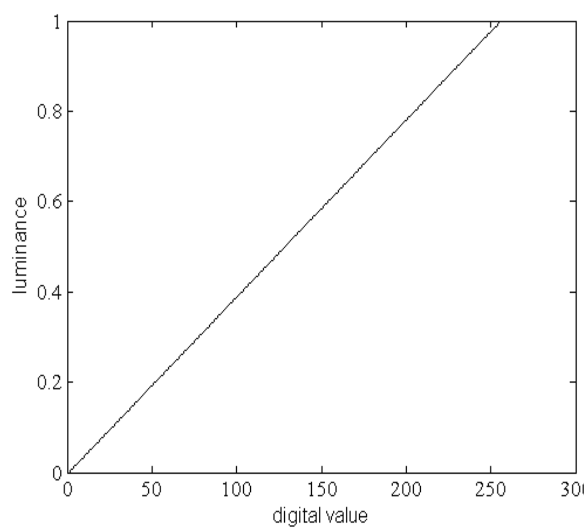


Fig. 8 the gamma function of a LEDs monitor

In Fig. 8 we have the LED monitor's gamma function, which shape is linear. In order to change the colors intensity we increase the LEDs' driving current. One pixel configuration can contain white LEDs. Other configurations contain red, green and blue LEDs in series or square pixel that contain four LEDs, in which situation a LED is doubled. The result of the LEDs current increase is the increase of the LEDs luminosity and colors temperature.

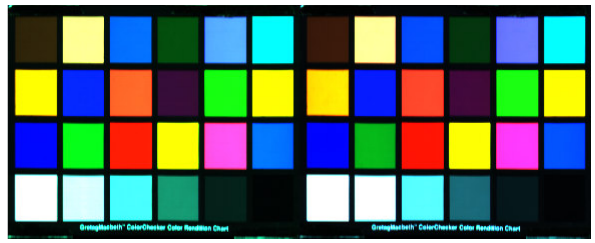
Since the operation lifetimes of the white and RGB LEDs are different, differential aging also results in luminance decay, color shift and panel nonuniformity. Some detectors can be implemented on the panel to compensate the brightness loss and correct the color performances [8,19].

The advantage of using the red, green and blues LEDs are that they spectral band is enough and the LCD's color filters are not necessary. The display colors come from the colors mixtures of the LEDs, rather than the color filters. Consequently the color filters are not needed in this scheme. Without the color filters, the fabrication process is simpler and the panel cost is reduced.

Generally speaking, the red, green and blue LEDs backlight illumination is used for large screen LCD monitors and TV. The white LEDs are used for some small size mobile LCDs, where the module size is more important than the colors performances.

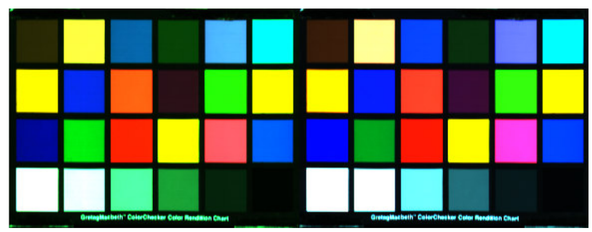
3.1 The colors text simulation results

Basing on the idea that the most important monitors' characteristic is colors rendering and assuming that we don't have problems related to resolution, we simulate the normal viewer colors perceptions on different monitors. In Fig. 3, Fig. 5 and Fig. 7 we see the SPD afferent to CRT, LCD and LEDs monitors'. We see that the monitors' spectrums present big differences and we expect also the render images to present different hues. In order to eliminate the hues we make the white balance. In Fig. 9 we have the image renders by the CRT monitor. Due to the shape of the monitor spectrum we have little hues differences between the monitor render image (Fig. 9 a)) and the white balance image (Fig. 9 b)). In Fig. 10 we have the image renders by the LCD monitor. Due to the shape of the monitor spectrum we expect to have some green hue on the text image (Fig. 10 a)). In Fig. 10 b) we have the correct image of the LCD monitor. In Fig. 11 we have the image renders by the LEDs (assuming that the entire monitor has a similar transfer function like the white led). Due to the LEDs shape (Fig. 7) we expect to have on the render image a hue that is a combination between the blue pick and the 500 to 700 band. In Fig. 11 a) we see the renders image and in Fig. 11 b) we see the corrected image for white LEDs monitor. In Fig. 12 we see the image render by the red, green and blue LEDs monitor. In Fig. 12 a) we have the renders image and we see that the colors are more intense. This monitor is suitable to render HDR images. In Fig. 12 b) we have the white balance image for the case of the RGB LEDs monitor.



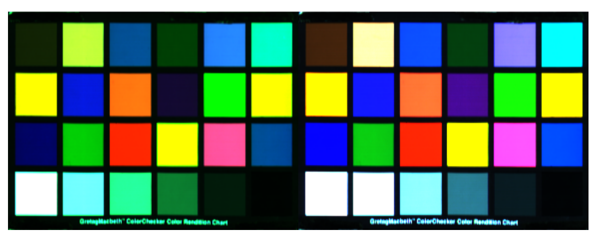
a b

Fig. 9 a) the CRT monitor's render colors,
b) the CRT monitor's white balance



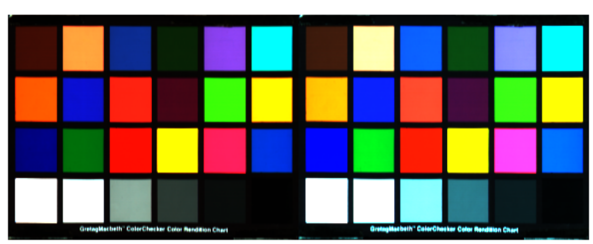
a b

Fig. 10 a) the LCD monitor's render colors,
b) the LCD monitor's white balance



a b

Fig. 11 a) the white LED monitor's render colors,
b) the white LED monitor's white balance



a b

Fig. 12 a) the RGB LED monitor's render colors,
b) the RGB LED monitor's white balance

In Fig. 9 a), Fig. 10 a), Fig. 11 a) and Fig. 12 a) we see that the render monitors images are very different. Happily after the white balance images correction (Fig. 9 b), Fig. 10 b) Fig. 11 b) and Fig. 12 b)) we see the final images colors, which seem to be the same. Also we notice that from the monitors' buttons we can change the brightness, luminosity and contrast, independent of our algorithm and function of the viewer needs.

4 The display colors properties

Peoples use to watch television and they appreciate the quality parameters of the rendered images like: luminosity, colors saturation, contrast, brightness and sharpness [2,4,6,10,11,14,16]. Luminance is a measure of radiant light energy that is based upon the logarithmic human visual response to light. The gamma functions (equation 6) more closely match the logarithmic response of the human eye.

4.1 The colors saturations

In color theory saturation or purity refers to the intensity of a specific hue [2,4,6,11]. The saturation of a color is determined by a combination of light intensity and how much it is distributed across the spectrum of different wavelengths. In order to have a more realistic image, we have to saturate the colors (Fig. 16 b)). To do that we multiply the image with a 3x3 matrix:

$$\begin{bmatrix} 1.4333 & -0.2667 & -0.2667 \\ -0.2667 & 1.4333 & -0.2667 \\ -0.2667 & -0.2667 & 1.4333 \end{bmatrix}. \qquad (7)$$

4.2 The contrast blending

Contrast is the difference in visual properties that makes an object distinguishable from other objects and the background. In visual perception of the real world, contrast is determined by the difference in the color and brightness of the object and other objects within the same field of view. In order to obtain the image contrast, we blend together images with different light exposure in order to obtain high dynamic range images (HDRI) [6,14,16,17]. The dynamic range is the difference between, or ratio, of the lightest and darkest elements on a printed or displayed image. The dynamic range of a real-world scene can be 100000:1.

This method is defined as that each pixel in the resulting image is an average of the pixels from all the exposures, but the weight for each pixel is different. This algorithm works for sets of multiple images, for example we take six images. The exposure can be changed by changing the integration time in the charge coupled device (CCD) that capture the image (basing on the example from reference [16,17]). In order to watch TV a HDRI, we need a HDRI camera, which capture the image and a HDRI display, which render the image. The concept of HD display is suitable for LCD display that use LEDs backlight illumination. The HDRI is obtained inside the HD camera when we look it at the TV. Other alternative is that the images with different light exposure (Fig. 13 to Fig. 15) to be blended or merged in order to make our own HDRI on a computer by using our proper or a dedicated blending algorithm [16,17].

Fig. 13 two degree of short light exposure

Fig. 14 two degree of medium light exposure

Fig. 15 two degree of long light exposure

We use the grayscale value of the long exposure as the weight of the short exposure because the bright pixels in the long exposure may be blown out or actually a bright object. In either case, we would want to use the pixel value in the short exposure. Dark pixels in the long exposure (since exposed longer) most likely represent a dark object in the scene. For each pixel, the resulting pixel is a weighted average of the short and long exposure pixel where the grayscale value of the long exposure pixel is the weight for the short pixel. The pixel is scaled such that energy of the pixels is not increased. This easily extends to multiple images. First, blend the two images with the longest exposure as described. This is repeated until all the images are used. This method works well, is computationally easy and in general does a pretty good job at blending the multiple exposures.

4.3 The brightening

Brightness is an attribute of visual perception in which a source appears to emit a given amount of light. In other words, brightness is the perception elicited by the luminance of a visual target. This is a subjective property of an object being observed. In the RGB color space, brightness can be thought as the arithmetic mean of the red, green, and blue color coordinates. In order to obtain the image brightness we multiply each color coordinate with a gauss function [2,6,11,14].

4.4 The sharpening

Some time images can be blurred, due to the camera's defocus or movement. A good monitor should have the possibility to correct this deficiency. In order to correct the blur and to preserve the impression of depth, clarity and fine details we have to sharp the image using a Laplacian filter [2,6,11,14,16,17]. A Laplace filter is a 3x3 pixel mask:

$$L = \begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}. \tag{8}$$

In order to restore the blurred image we subtract the Laplacian image from the original image.

4.5 Texting the display color properties

In our simulation we use an image that was taken with a digital camera which doesn't have the gamma correction (Fig. 16 a)). Our task is to enhance the images parameters [14] using the TV's remote control or the monitor's display buttons. In Fig. 16 b) we have the image with gamma correction and colors saturation, and we see that the luminosity and colors are enhanced. In Fig. 17 a) we have the blend high dynamic range image with enhance contrast, this is the best of our simulate images and it has good contrast, luminosity and colors. In Fig 17 b) we have the HDRI with increase brightness, as a result the image shine too much. Some time images can be blurred due to camera defocus or movement. In Fig. 18 we have the blur image and the recover sharp image. In our situation the Laplace filter does a good image recovery.

a b

Fig. 16 a) the original image, b) the image with gamma correction and colors saturation

a b

Fig. 17 a) the contrast image, b) the brightness image

a b

Fig. 18 a) the blur image, b) the sharp image

Conclusions

In this paper we try to present some aspects regarding the human eyes perception of the monitors' colors rendering. We focus our attention on different monitors' colors rendering, in function of their SPD. Using the proposed spectral image processing algorithm, we simulate the colors perception render by a CRT, a LCD and a LED monitor. Also we present the monitor's colors properties like: colors saturation, brightness, contrast and sharp. Because the monitors present constructive and functional differences, if someone wants to buy a display device, first is recommended to read carefully the display characteristics which are presented in a device profile file. The CRT monitors represent an old technology. The LCD monitors are the nowadays technologies. The LEDs monitors represent an interesting approach for future technologies development.

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