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Colorimeters and Spectrophotometers - their professional use for measurement of colors in Design Prototyping

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ENG

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Author: Prof. MA.GD. Milot Gusia

Description:

In professional measurement of colors in various surfaces of design models, there have been significant challenges posed by traditional color models that have made the accurate measurement and notation of colors difficult. This paper examines the use of colorimeters and spectrophotometers in accurate measurement of colors and of results obtained in coordinates within the various color spaces such as: CIE XYZ (Yxy), L*a*b*, L*C*h*, Hunter Lab, and Munsell. The paper starts by explaining the use of colorimeters in design, through three sensors calibrated in conformity with the sensitivity of human eye, hence obtaining the colors in three stimulus method. Furthermore, the paper explains the use spectrophotometers, which despite colorimeters has multiple sensors, hence as a more sophisticated instrument, gives a more thorough information regarding the colors of design models by means of SPD (Spectral Power Distribution).

Keywords: Spectrophotometers, Colorimeters, Design Prototyping, Color Calibration in Design.

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Kolorimetrat dhe Spektrofotometrat – përdorimi i tyre profesional për matjen e ngjyrave në Prototipat e Dizajnit

Autor: Prof. MA.DG. Milot Gusia

Përshkrim:

Në matjen profesionale të ngjyrave në sipërfaqe të ndryshme të modeleve të dizajnit, ka pasur sfida të rëndësishme të paraqitura nga modelet tradicionale të ngjyrave që kanë bërë të vështirë matjen dhe shënimin e saktë të ngjyrave. Ky punim shqyrton përdorimin e kolorimetrave dhe spektrofotometrave në matjen e saktë të ngjyrave dhe të rezultateve të marra në koordinata brenda hapësirave të ndryshme ngjyrash si: CIE XYZ (Yxy), L*a*b*, L*C*h*, Hunter Lab , dhe Munsell. Punimi fillon duke shpjeguar përdorimin e kolorimetrave në dizajn, përmes tre sensorëve të kalibruar në përputhje me ndjeshmërinë e syrit të njeriut, duke marrë kështu ngjyrat në metodën tre stimuluese. Për më tepër, punimi shpjegon përdorimin e spektrofotometrave, të cilët përkundër kolorimetrave posedojnë sensorë të shumëfishtë, pra si instrumente më të sofistikuara, japin një informacion më të plotë në lidhje me ngjyrat e modeleve të dizajnit duke siguruar gamën e plotë SPD (të Fuqisë së Distribuimit Spektral).

Fjalët kyçe: Spektrofotometrat, Kolorimetrat, Prototipat e Dizajnit, Kalibrimi i Ngjyrave në Dizajn.

Colorimeters and Spectrophotometers - their professional use for measurement of colors in Design Prototyping

Prof. MA.DG. Milot Gusia

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UBT College

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In professional measurement of colors in various surfaces of design models, there have been significant challenges posed by traditional color models that have made the accurate measurement and notation of colors difficult. This paper examines the use of colorimeters and spectrophotometers in accurate measurement of colors and of results obtained in coordinates within the various color spaces such as: CIE XYZ (Yxy), L*a*b*, L*C*h*, Hunter Lab, and Munsell. The paper starts by explaining the use of colorimeters in design, through three sensors calibrated in conformity with the sensitivity of human eye, hence obtaining the colors in three stimulus method. Furthermore, the paper explains the use spectrophotometers, which despite colorimeters has multiple sensors, hence as a more sophisticated instrument, gives a more thorough information regarding the colors of design models by means of SPD (Spectral Power Distribution).

Keywords: Spectrophotometers, Colorimeters, Design Prototyping, Color Calibration in Design.

Introduction

In professional measurement of colors in various surfaces of design models, there have been significant challenges posed by traditional color models that have made the accurate measurement and notation of colors difficult.

Visual identification of colors through hue, value and saturation is a form of color reproduction for artistic creations. But, this form of reproduction cannot be used in various industries, such as textile design, interior, fashion, architecture, restoration, archeology, printing, etc., where color reproduction it must be extremely accurate.

Perceived color is a matter of individual and subjective interpretation. Different individuals, even when looking at an identical color, based on different physiological abilities and individual experiences will express it in different ways.

Since there are many ways to express color, describing a particular color is extremely difficult and not objective. If we write a color like: "fiery red", can we expect others to imagine that color accurately? The verbal description of color is very complicated and difficult.

Color names have changed throughout history. For example, the color red has many names, such as: "vermilion", "cinnibar", "crimson", "pink", “strawberry", "scarlet" etc. These are considered the common color designations.

While the systematic designations give the color visual epithets, such as: "bright red" etc.

Although common designations and systematic designations exist, these do not meet the requirements for accurate color communication required in the graphic, architectural, and printing industries.

Therefore, there are standard color grading methods by which colors are expressed with great accuracy. Through these standards the communication of color is much more crystallized, simpler and more accurate.

Such color communication eliminates the problems of accurate color reproduction.

The influence of different conditions in color perception

We will mention some other factors beside subjective human perception in color deception.

Changes in the source of illumination

A color that looks brilliant in sunlight looks colder under fluorescent interior light.

Each type of light source, such as: sunlight, fluorescent light, incandescent light, etc., will change the appearance of the color (fig. 1), therefore in professional grading systems, standard light sources have been developed that ensure a constant appearance of color.

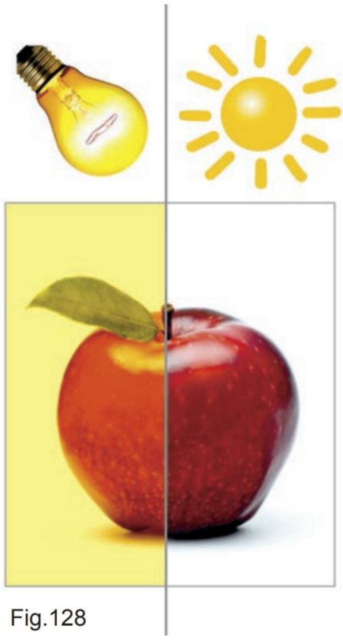


Figure 1- Influence of Light Source in Color Perception. Source: Milot Gusia "Ngjyra, Teoria dhe Përdorimi Praktik", , 2013. ISBN: 978-9951-8825-1-4

Change of the background

If a colored object is placed in front of a bright background, it appears duller than if it were placed in front of a dark background. This phenomenon is known as the Simultaneous Contrast, and it is an effect that negatively affects the personal appreciation of colors. (Nasa, 2023)

Therefore, professional grading systems are not affected by the effect of Simultaneous Contrast.

Change of direction

Only a slight change of viewing angle during viewing an object's color may vary the appearance of its color.

This happens because of color direction characteristics. Some colored materials, especially metallic colors, have pronounced driving characteristics. The corner from which an object is viewed, as well as the angle from which lights falls, must be constant for precise communication of color (Philips, 2024). Therefore, professional grading systems of colors are illuminated and evaluated by a standard angle.

Viewer changes

The sensitivity of each individual's eyes varies slightly; even for people with "normal" color vision, there can be a fluctuation in red and blue colors.

Also, a normal person's vision changes with age. Because of these factors, colors look different to different individuals (Nir Erdinest et al. 2021).

Therefore, in professional grading systems, colors are marked numerically

Changes in size

Colors that cover a large area tend to appear brighter and more intense than colors that cover a small area. This is known as the surface effect.

Selecting objects that will cover a large area of color based on samples of small areas of color will result in errors.

Color Grading Systems

All the above-mentioned arguments prove the reason why there is a need for the development of systems that enable the communication of colors with absolute accuracy.

These systems are standards used in the textile design, interior, fashion, architecture, restoration, archeology, printing, etc.

Therefore, knowledge of these standards is necessary for every artist, designer or architect.

The Munsell Color System

Munsell system for the first time enabled the exact description of color, which could also be justified on scientific grounds. Munsell System defines colors in three dimensions, that of Hue, Value and Chroma (Munsell, 2023).

Color is defined as concrete color, or, red, blue, green, etc. The value is defined as the degree of lightening or darkening of the color.

Chroma is defined as the degree of color intensity.

Munsell atlas achieved what was until then considered impossible, the scientific definition of the three-dimensional parameters of color.

NCS Color System

The Swedish NCS (Natural Color System) originates from Ewan Hering's opponent theory.

This system operates with six primary colors proposed earlier and by Leonardo da Vinci himself (NCS, 2024).

Preliminary research on this system has also included Johansson's Squares system and Sven Heselgren's color atlas (Anders Hård et al. 1996).

The project was initiated in 1964, with the results revealed only at the end of the 20th century by Anders Hård and Lars Sivik.

The objective of the Swedish color researchers was to establish a system of colors by means of which the user, with normal vision, can define colors without the need for instruments gauge or for color samples.

The natural color system contains a double cone-shaped contour and is constructed so that the four basic psychological colors, yellow (Y), red (R), blue (B) and green (G) are located on four points of the circular base. The top of the double cone is white, while the bottom is black (NCS, 2024).

Colorimetry and Spectrophotometry

There are several different instruments that measure color using different methods. Through it the data from these instruments can be obtained the correct orientation coordinates within the spaces different color such as: CIE XYZ (Yxy), L*a*b*, L*C*h*, Hunter Lab, Munsell etc.

The simplest color measuring instruments are colorimeters, consisting of three filtered sensors for having the same sensitivity as the human eye.

Figure 2 - Konica Minolta colorimeter. It measures the color by means of three sensors with the tristimulus method, therefore it is more limited than the spectrophotometer.

As the human eye does, so do colorimeters color measurement with the tristimulus method. But, the light can be characterized with higher precision if its strength is measured at each wavelength within visible spectrum (Philips, 2024).

The result called Spectral Power Distribution (SPD) contains all the data basic physics on light and serves as a starting point of quantitative color analysis. SPD can be measured through the spectrophotometer.

Despite the colorimeter, the spectrophotometer has multiple sensors, therefore it is a more sophisticated instrument that provides data more complete on the color of an object.

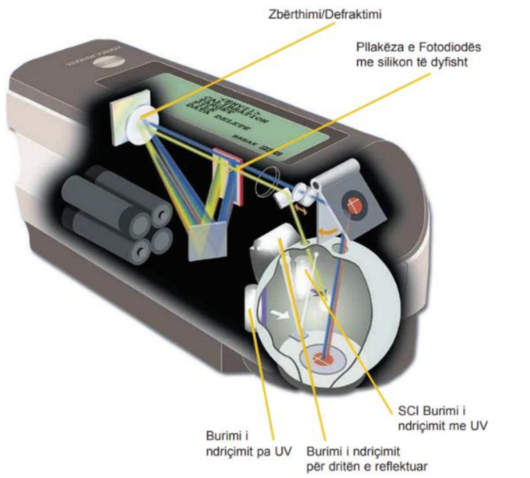


Figure 3 - Konica Minolta CM-2600d Portable Spectrophotometer it measures the color by means of multiple sensors, therefore it is more sophisticated than the colorimeter.

By using the colorimeter, we can immediately obtain the numerical data of the color in the tristimulation method that enables us to orientate in each color space (Philips, 2024).

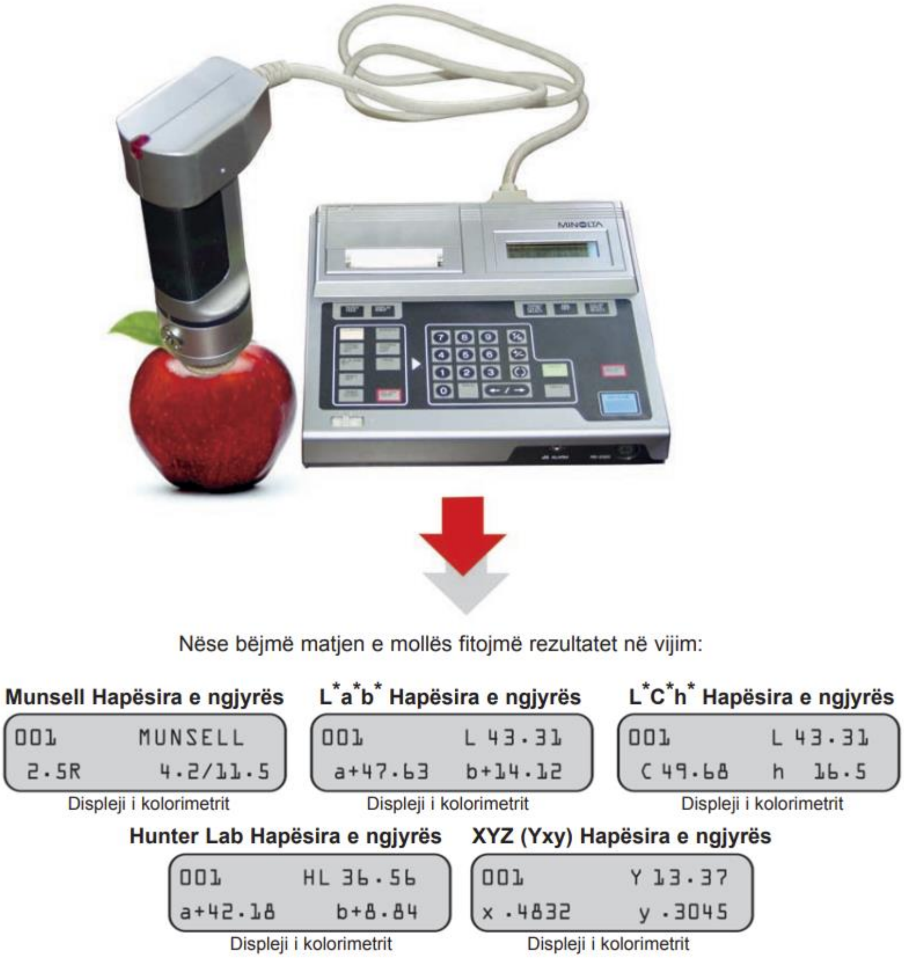


Figure 4 - Colorimeter Display in various color Spaces.
Source: : Milot Gusia "Ngjyra, Teoria dhe Përdorimi Praktik", 2013. ISBN: 978-9951-8825-1-4, page 319

Using the colorimeter in the L*a*b* color space

The L*a*b* color space (also known as CIELAB) is today one of the most popular spaces for measuring color and is widely used in almost all fields of art and industry.

This is a uniform space of color defined by the CIE in 1976 with purpose of reducing one of the biggest problems that were displayed in the first XYZ color space (Yxy): the equivalent spaces in the x and y chromaticity diagram did not correspond to equivalent perceived color changes (CIE, 2004).

In this space, L* represents the brightness, while a* and b* are the chromaticity coordinates (Datacolor, 2024).

Fig.5 illustrates a* and b* chromaticity diagram.

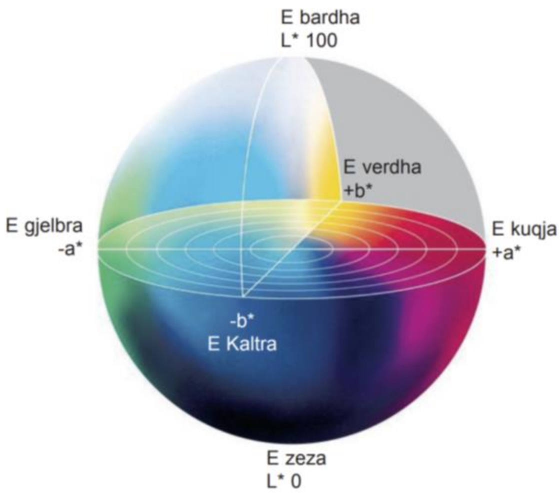


*Figure 5 - Complete three-dimensional space of color L*a*b* Source: : Milot Gusia "Ngjyra, Teoria dhe Përdorimi Praktik", 2013. ISBN: 978-9951-8825-1-4, page 320*

In this diagram a* and b* indicate color directions: +a* is red direction, -a* is green direction, +b* is the yellow direction, and –b* is the blue direction.

The center is achromatic; with increasing values of a* and b* the point moves away from the center, and thus also increases color saturation.

In order to understand what the values in figure 6 present in the display of the colorimeter, let's first put the values a* and b* (a*=+47.63, b*=+14.12) in the diagram a*, b* of the L*a*b* color space (fig. 7) to earn the point (A), which shows the chromaticity of the apple.

L* value (43.31) shows that this red is more dark, since the L* value in the L*a*b* color space is the brightness meter and ranges from 0 (black) to up to 100 (white).

Fig. 7 shows the horizontal section of the space L*a*b* illustrated in full form in fig.5.

If we measure the apple using space of color L*a*b*, we get the following values

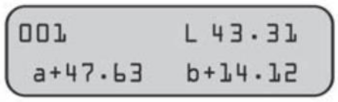


*Figure 6 - The values obtained by measuring object color (apple) in L*a*b* Color Space. Source: Milot Gusia "Ngjyra, Teoria dhe Përdorimi Praktik", , 2013. ISBN: 978-9951-8825-1-4*

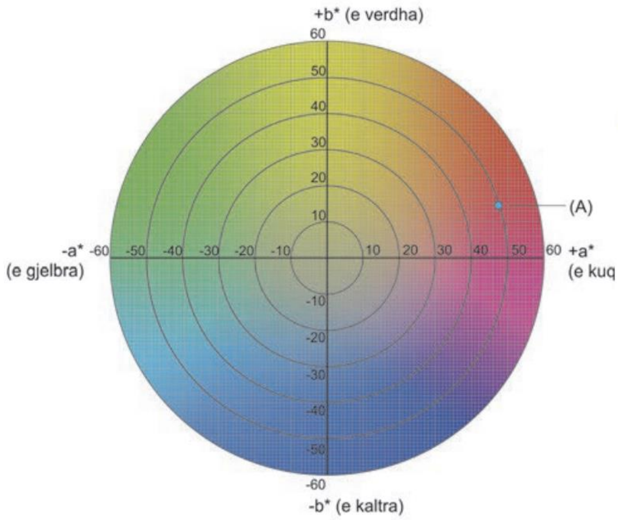


*Figure 7 - Horizontal section of the space color L*a*b* where are illustrated the chromaticity coordinates of the apple (A). Source: Milot Gusia "Ngjyra, Teoria dhe Përdorimi Praktik", , 2013. ISBN: 978-9951-8825-1-4*

Using the colorimeter in the L*C*h color space

The L*C*h color space uses the same diagram as well as the L*a*b* color space, but in instead of rectangular coordinates, cylindrical coordinates are used (Konica Minolta, 2024).

In this color space, L* introduces the brightness parameter and is e same as the L* value of the L*a*b* color space, C* is the chroma, and h is the hue angle.

Value of chroma C* is 0 at the center and rises depending on the distance from the center.

Color angle h starts on the +a* axis and is expressed in degrees: 0° is equal to +a* (red), 90° is equal to +b* (yellow), 180° is equal to -a* (green), and 270° is equal to -b* (blue).

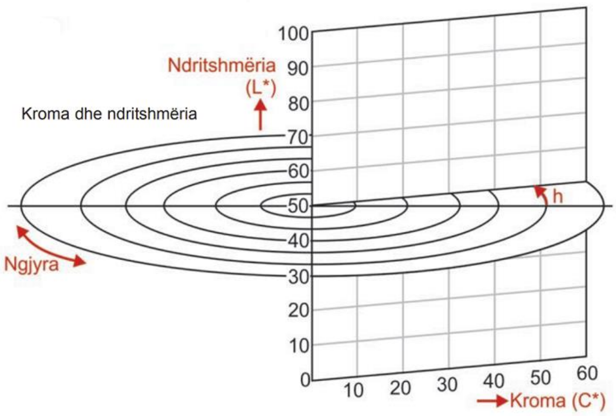


*Figure 8 - Chroma and brightness L*C*h color space. Source: Milot Gusia "Ngjyra, Teoria dhe Përdorimi Praktik", 2013. ISBN: 978-9951-8825-1-4, page 321.*

If we do measuring the apple through the color space L*C*h, we will get the following data (Fig.9).

If i we put these data in the diagram (fig.10), we obtain the point of the apple color coordinate (A).

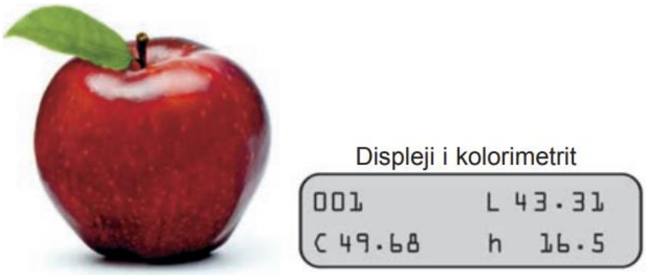


*Figure 9 - The values obtained by measuring object color (apple) in the L*C*h color space. Source: Milot Gusia "Ngjyra, Teoria dhe Përdorimi Praktik". . 2013. ISBN: 978-9951-8825-1-4*

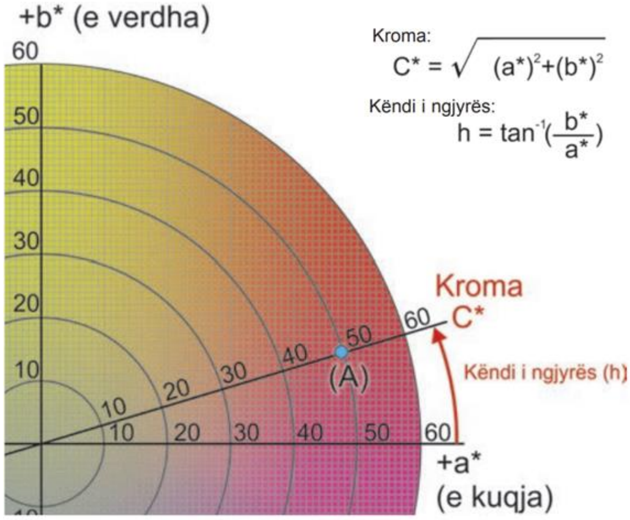


*Figure 10 - Diagram of L*C*h color space.*

Using the colorimeter in the Hunter Lab color space

The Hunter Lab color space was developed by R. S. Hunter as a more visually uniform color space than the CIE color space 1931 Yxy (Fig.11).

Similar to the CIE L*a*b* space, this space remains in use in the different fields, as in the paint industry in the USA (HunterLab, 2023).

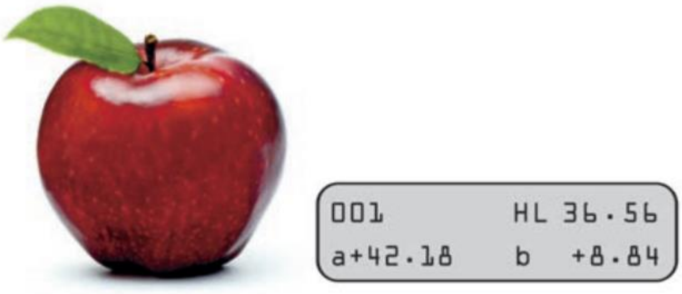


Figure 11 - The values obtained by measuring object color (apple) in Hunter Lab color space. Source: Milot Gusia "Ngjyra, Teoria dhe Përdorimi Praktik", , 2013. ISBN: 978-9951-8825-1-4

Using the colorimeter in the CIE (Yxy) color space

The tristimulus values XYZ and the corresponding color space Yxy form the basis of the CIE color space (CIE, 2004).

The concept of XYZ tristimulus values is based on the three-component theory of human vision, which states that the human eye possesses receptors for three primary colors (red, green, and blue) and all colors are perceived as mixtures of these three primary colors (CIE, 2004).

Values XYZ tristimulus are calculated using Standard Observer color adaptation functions, of which we described in the previous units.

If we measure the color of the apple using the Yxy color space, we get the values x=0.4832, y=0.3045 as chromaticity coordinates, which correspond to point (A) in the diagram in fig.12;

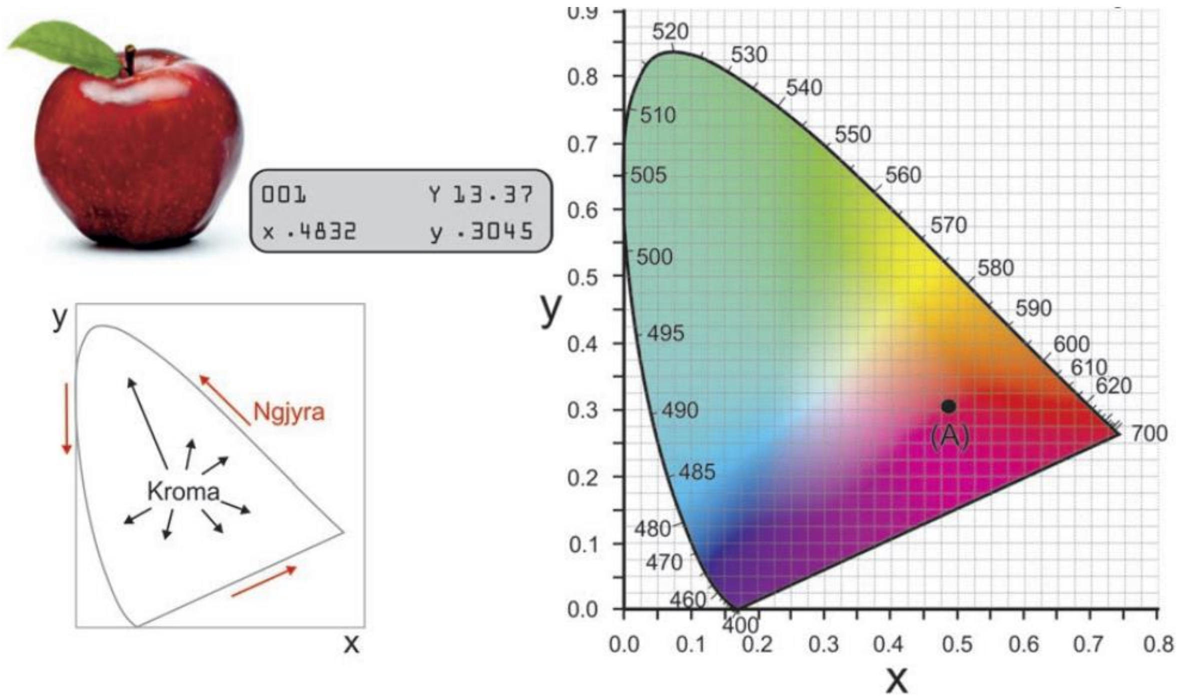


Figure 12 - The values obtained by measuring object color (apple) in CIE (Yxy) color space. Source: Milot Gusia "Ngjyra, Teoria dhe Përdorimi Praktik", , 2013. ISBN: 978-9951-8825-1-4

Value Y 13.37 indicates that the apple has a reflectance of 13.37%.

Measuring the color of objects using a colorimeter

Although the human eye cannot distinguish colors with absolute accuracy, by means of colorimeter this is simple.

Despite commonly used subjective expressions in color description, colorimeters express the color in numerical form according to international standards (Philips, 2024).

By describing colors in this form, color communication and color accuracy becomes possible in all areas of art, design and industry.

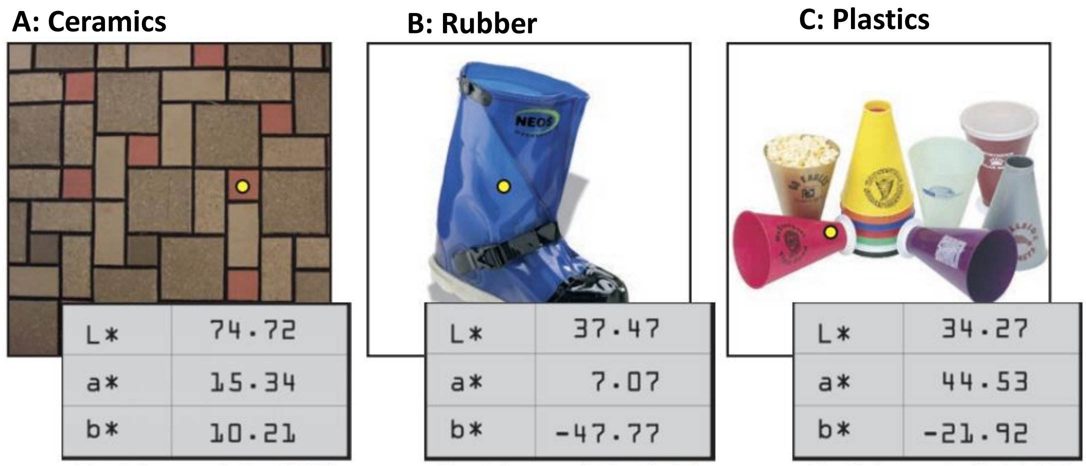


Figure 13 - The values obtained by measuring colors of objects of various materials through Colorimeter. Source: Milot Gusia "Ngjyra, Teoria dhe Përdorimi Praktik", , 2013. ISBN: 978-9951-8825-1-4

Colorimeters have sensors that correspond to the human eye, and measurements are performed through the internal source of lighting, so the measurement conditions remain always constant, regardless of the external conditions (Philips, 2024).

At any period of time and under any different atmospheric conditions, such as during the day or at night, indoors or outdoors, colorimetry makes the color measurement always constant, precise and simple.

Small differences between colors are one of the most difficult problems to spot during color delivery. But with the colorimeter, even the smallest changes can be expressed numerically and described with ease.

For example, use the L*a*b* and L*C*h color spaces to spot the differences between the color of the two apples using the color of apple 1 (L*=43.31, a*=+47.63, b*= +14.12) as standard.

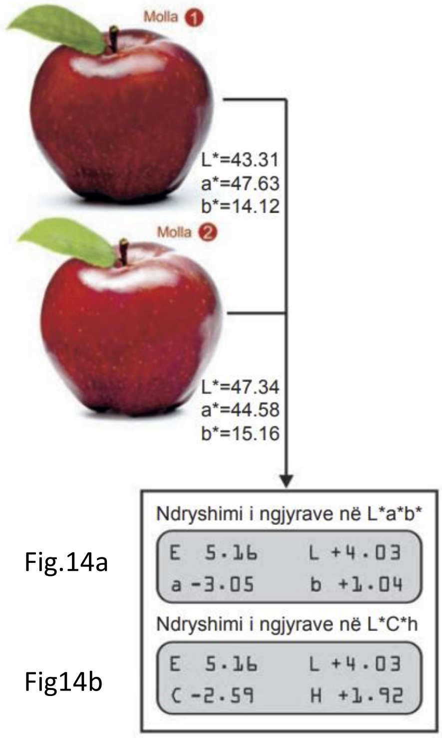


Fig.14a

Fig14b

Figure 14 - The values obtained by measuring colors of objects (apple 1 and 2) through Colorimeter.

If we measure the changes between the color of apple 2 (L*=47.34, a*=+44.58, b*=+15.16) and apple 1, we get the results illustrated in fig.14 and below it in fig.14b.

In the L*a*b* color space, the difference between colors can be expressed by a single numerical value ΔE*ab, which represents the magnitude of the difference between colors.

ΔE*ab is defined through the following formula: ΔE*ab=[(ΔL*)2 + (Δa*)2 + (Δb*)2]1/2.

If we give the values from the colorimeter display (fig.14) ΔL*=+4.03, Δa*=-3.05, and Δb*=+1.04 in the formula above, we get ΔE*ab=5.16, which is the value shown in the upper left corner of the square.

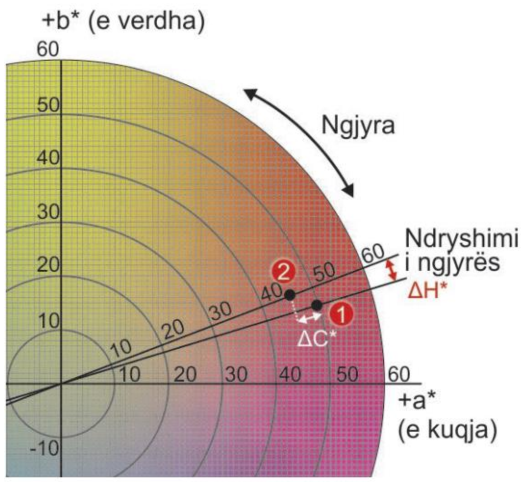


Figure 15 - ΔH in L*C*h color space. Source: Milot Gusia "Ngjyra, Teoria dhe Përdorimi Praktik", , 2013. ISBN: 978-9951-8825-1-4*

If we measure the color change between the two apples using the space e color L*C*h, we get the results shown in the panel of Fig.14b.

The ΔL* value is the same as the space value of color L*a*b*.

ΔC*=-2.59 indicates that the color of apple 2 is less saturated. The change in color between two apples, denoted by ΔH*. ΔH* is +1.92 illustrated in fig.15.

It can be seen that the color of apple 2 is closer to the +b* axis, which indicates it is more yellow.

Although words are not like numbers, we can use the words to describe the differences between colors.

If we analyze the values of color data of the two apples in the diagram, we can say that the color of apple 2 is paler than color of apple 1.

Since there isn't a big difference in the Chroma of two apples, then we can add that apple 2 is "slightly fainter" to emphasize the scale of change.

Characteristics of the Colorimeter

- The colorimeter has its own light source integrated and the system that ensures uniform lighting of objects in all types of measurements, while the data can be calculated by based on CIE standard illuminants C or D65.
- Measurement data can be automatically saved and printed. The results of the measurements are presented on the display in precise numerical form in different spaces color to ensure accurate color communication.
- Colorimeter sensors are calibrated through filters to match CIE 1931 functions. of color adaptation (or Standard Observer), therefore the observation conditions are constant in all kinds of measurements.
- After the colorimeter measures the samples (provided the sample diameter is at least a minimum size), the effects of different sizes or backgrounds are eliminated.

Spectrophotometry

When we measure objects with a colorimeter (with the tristimulus method), we can obtain only numerical data on color and use them for orientation in different spaces of color.

But if we use the spectrophotometer, beside obtaining numerical data (fig.16), through multiple sensors (40 in total in the Minolta CM 2600d spectrophotometer) we can measure the complete wavelength region of visible light, thus making the measurement of the strength of the object's light spectral distribution (or SPD) (Philips, 2024).

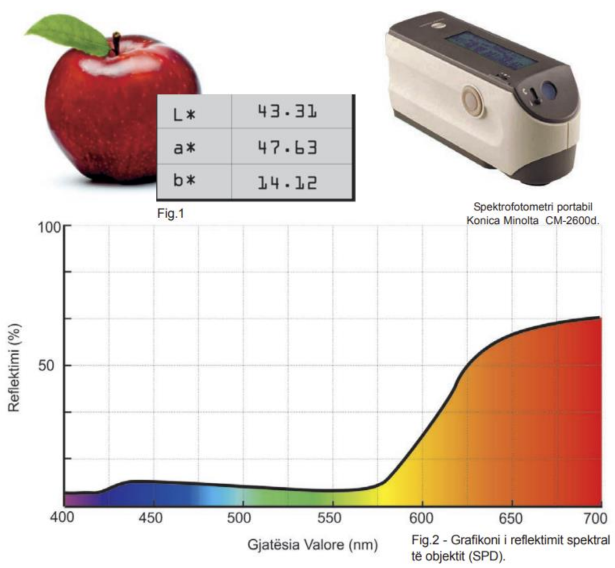


Figure 16 - Measuring color with portable Spectrophotometer Konica Minolta CM-2600d. Source: Milot Gusia "Ngjyra, Teoria dhe Përdorimi Praktik", , 2013. ISBN: 978-9951-8825-1-4

With this form of measurement we obtain the spectral reflection graph of the color of an object (fig. 16).

This is called a spectrophotometric method of color measurement.

Multiple high precision sensors and data for different lighting conditions from different illuminants give the spectrophotometer the ability to provide even greater accuracy than the data obtained by means of the colorimeter.

Any colored object from the light source absorbs a portion of light, while the rest is reflected. This reflected light enters in the human eye, and the resulting retinal stimulation is e registered by the brain as the "color" of the object.

Each object absorbs and reflects light from different parts of the spectrum. Also, the parts are reflected in different amounts.

These changes in absorption and reflection are the properties that make the colors look different.

If we measure the SPD of an apple, we obtain the spectral graph illustrated in fig.17.

If we analyze this graph, we will notice that in the red region of wavelengths the amount of reflected light is high, but in other wavelength regions the amount of reflected light is small.

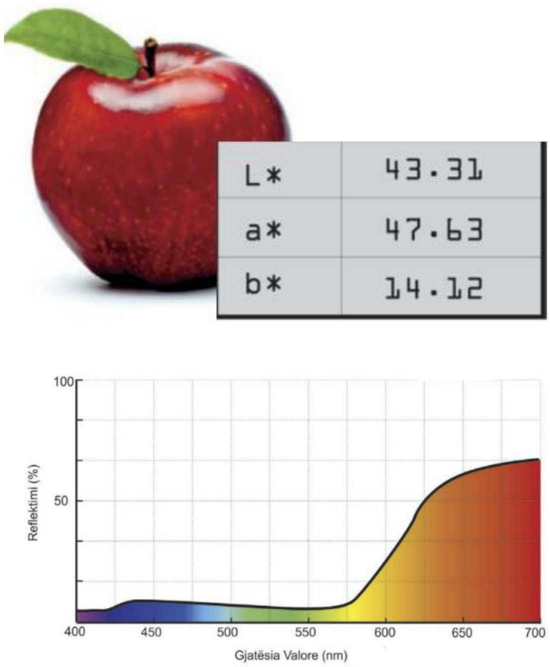


Figure 17 - Spectral reflectance graph of object (Apple)

Figure 17. illustrates that the apple reflects light in the orange and red region, whereas absorbs light in the green region, blue, indigo, and purple.

In this way, making the measurement by means of a spectrophotometer and unfolding the data in display in the form of a spectral graph, we can analyze the nature of the color of apple or any other object.

Each of the multiple sensors (a total of 40 in the Minolta CM 2002 spectrophotometer) of the spectrophotometer measures the light in its corresponding visible light wavelength region.

For this reason, the spectrophotometer can measure the changes within the objects color which are imperceptible from the human eye.

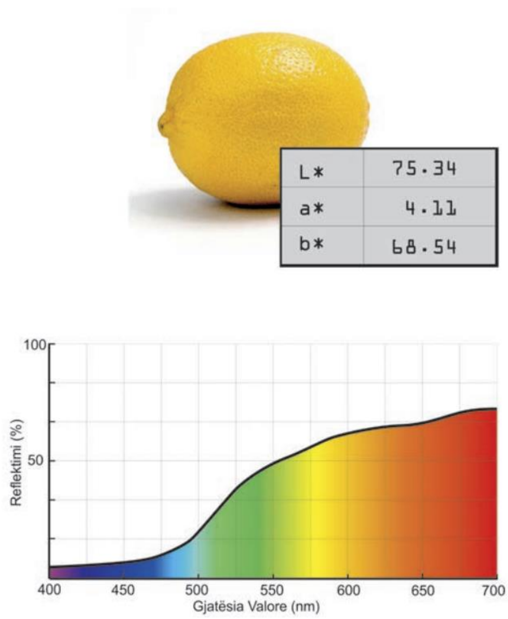


Figure 18 - Spectral reflectance graph of object (Lemon). Source: Milot Gusia "Ngjyra, Teoria dhe Përdorimi Praktik", , 2013. ISBN: 978-9951-8825-1-4

If we measure the strength of the spectral distribution (or SPD) of another object (lemon) we can obtain the spectral graph illustrated in fig.18.

If we analyze this graph, we see that in the red and yellow long wavelength region the amount of reflected light is high, but in the indigo region and violet wavelengths amount of light reflected is low.

Fig.18 illustrates that lemon reflects light in green, yellow and red wavelengths, whereas it absorbs light in the region of indigo and violet wavelengths. This is the nature of the color of the lemon fruit.

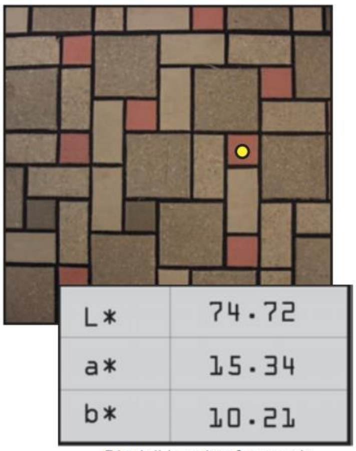
Such precision is e impossible to reach by the human eye hardly or even by use of the colorimeter, which, as we pointed out in the previous unit, is more limited to the data it can provide. This can only be achieved through the spectrophotometer.

Measurement of various objects by means of a spectrophotometer

A: Ceramics

Analyzing the graph of the spectral reflection of the pink plate (fig.19), we can notice that The ceramic plate reflects light at all wavelengths, and that the spectral reflectance at wavelength of 600nm (orange and red region) is slightly higher than in the region of other wavelengths.

A: Ceramics **B: Rubber** **C: Plastics**



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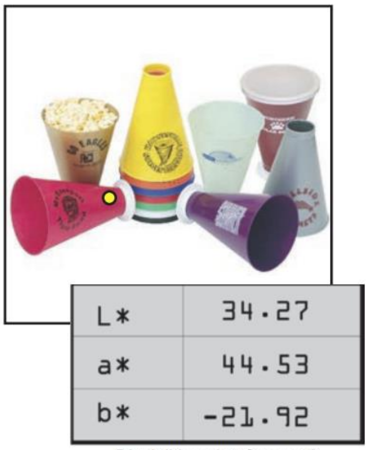

Displeji i spektrofotometrit

B: Rubber

Spectral reflectance of the rubber object in the wavelength region of 400 to 500 nm (indigo and cyan regions) is high, and spectral reflectance at longer wavelengths longer than 550nm is low, with almost all the color absorbed in this region (fig.19).

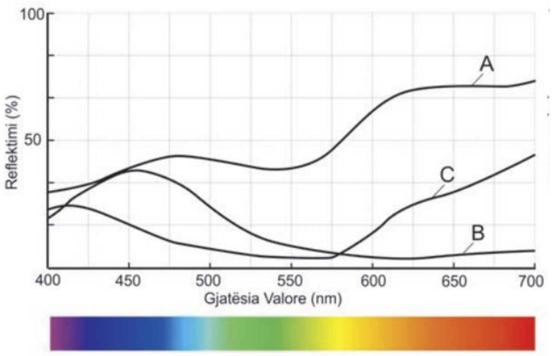

Figure 19 - Graphs of spectral reflectance of objects A, B, C

C: Plastic

The region around 400nm and 700nm of red-violet plastic has a spectral reflectance high, while the region of wavelengths from 500nm to 600nm has a low spectral reflectance, therefore we can observe how the light is absorbed in this region (fig.19)

Tristimulus and spectrophotometric method of color calculation

The tristimulus method measures the light reflected from the object with three filtered sensors which have the sensitivity identical to the human eye by doing so calculating directly X, Y and Z values.

On the other hand, the spectrophotometric method, makes use of multiple sensors to measure the spectral reflectance of object at each wavelength. The instrument's microcomputer then calculates the tristimulus values from the spectral reflectance data by means of integral calculations.

Color change as a result of changing light source

Different lighting sources will also vary the appearance of colors.

For color measurement, the CIE system has defined the spectral characteristics of different lighting sources standards or standard luminaries.

Fig. 20 illustrate the strength of the spectral distribution of some of standard illuminants.

The spectrophotometer processes the data on the color of an object by recording the strength of its spectral distribution, and then combining this acquired data with the data of different standard illuminants which it has stored in its memory.

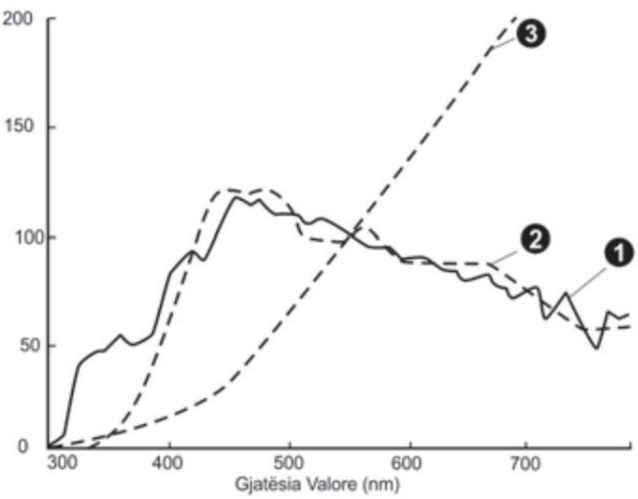

Figure 20 - The strength of the spectral distribution of some of standard illuminants. Source: Milot Gusia "Ngjyra, Teoria dhe Përdorimi Praktik", , 2013. ISBN: 978-9951-8825-1-4

Standard lighting sources or Standard lamps

Standard lamp D65-Standard daylight (not including the region of ultraviolet wavelengths) with color temperature 6504K; should be used for measuring the color of objects which will be illuminated by daylight including ultraviolet radiation (Fig.20, graph 1)

Standard Illuminant C – Standard daylight (not including the region of ultraviolet wavelengths) with color temperature 6774K; should be used for measuring the color of objects which will be illuminated by daylight excluding ultraviolet radiation (Fig.20, graph 2).

Standard Lamp A – Incandescent light with color temperature of 2856K; should be used for measuring the color of objects which will be illuminated by incandescent lamps (Fig.20, graph 3).

Fluorescent lamps (recommended by CIE as standard)

F2: "Cool White" (Fig.21, graph 4)

F7: "Daylight" (Fig.21, graph 5)

F11: "Three narrow band cool white" (Fig.21, graph 6)

Note:

The colorimeter has the data only for the standard illuminant 1 and 2

The spectrophotometer has the data of all standard illuminants 1-6.

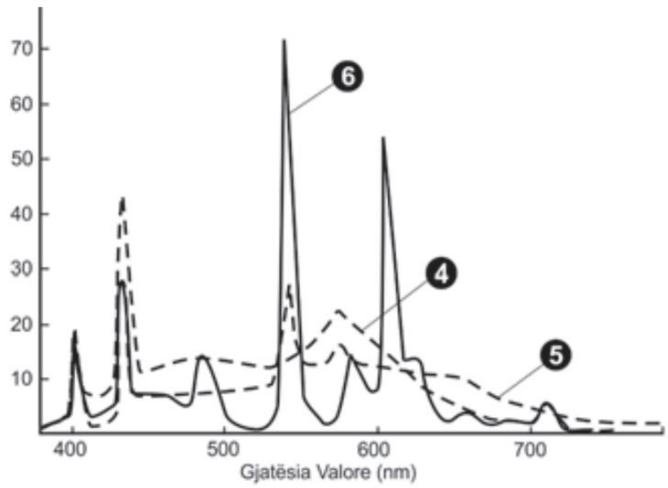

Figure 21 - The strength of the spectral distribution of Fluorescent lamps (recommended by CIE as standard). Source: Milot Gusia "Ngjyra, Teoria dhe Përdorimi Praktik", , 2013. ISBN: 978-9951-8825-1-4

The measurement of Spectral power distribution (SPD)

The measurement by means of the spectrophotometer of the force of spectral distribution of objects under different standard illuminants.

As we explained in the previous unit, the spectrophotometer has it in its memory saved data for different sources of lighting, namely for luminaries different standards.

If we analyze through the examples, object (apple) measured by means of spectrophotometer under standard illuminant D65 (Fig.22) and under the standard illuminant A (Fig.23).

In example 1, the graph illustrates the Spectral Power Distribution of standard Illuminant D65 (A) and spectral reflectance graph from object (apple) (B).

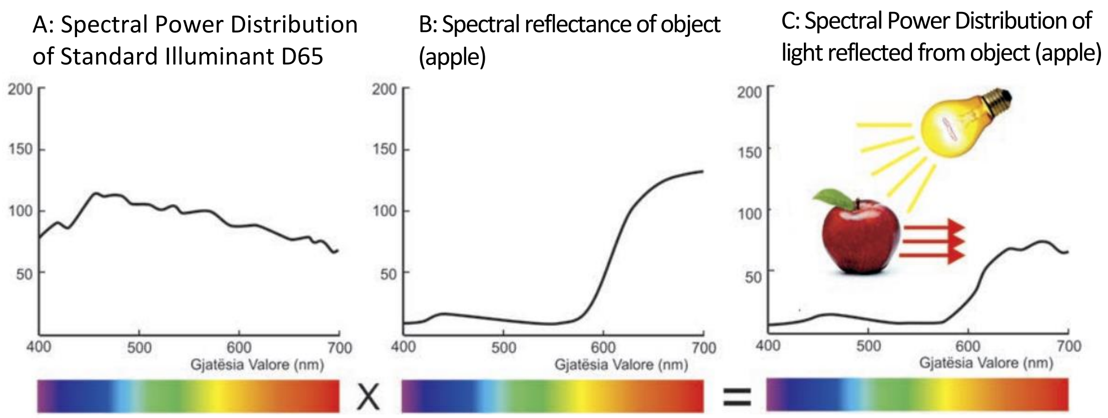

Figure 22 - Object (apple) measured by means of spectrophotometer under standard illuminant D65. Source: Milot Gusia "Ngjyra, Teoria dhe Përdorimi Praktik", , 2013. ISBN: 978-9951-8825-1-4

C presents the strength of Spectral Power Distribution of light reflected from the object (apple) and is the result of the multiplication of A and B.

In example 2, A' is Spectral power distribution (SPD) of the standard illuminant A, while B' is the spectral reflectance of the object (apple).

C' is the strength of the spectral distribution of light reflected from the object (apple) and is also the summation of A' and B'.

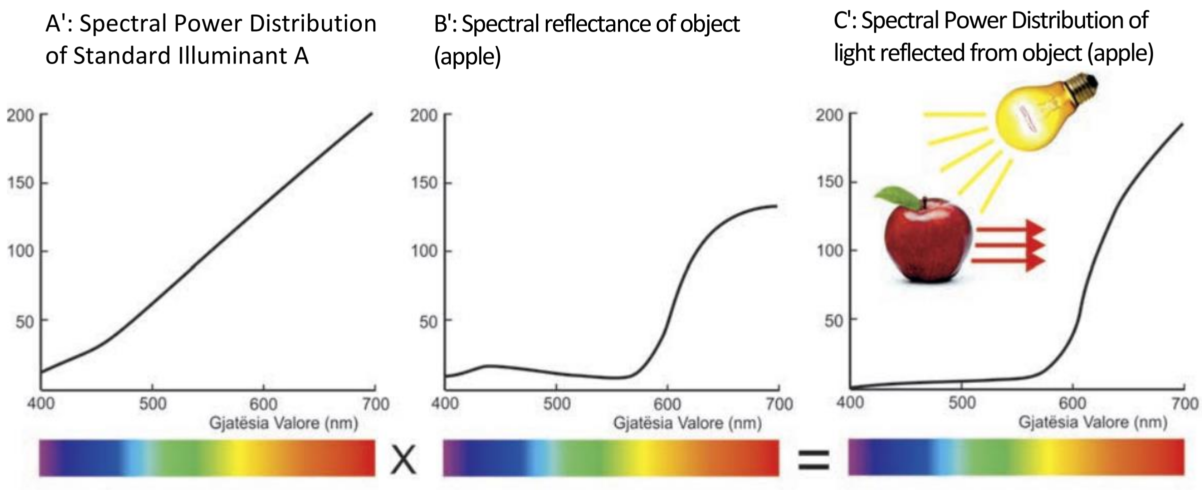

Figure 23 - Object (apple) measured by means of spectrophotometer under standard illuminant A.
Source: Milot Gusia "Ngjyra, Teoria dhe Përdorimi Praktik", , 2013. ISBN: 978-9951-8825-1-4

If we compare figures C and C', we will notice that in case C' the light in the red region is much stronger, which means that the apple will appear much redder under the standard illuminant A.

This shows that the color of an object changes depending on the illumination through which the object is perceived.

The spectrophotometer actually only measures the spectral reflectance of the object; the instrument then using its memory can calculate numerical values in different color spaces using the data in its memory of the strength of the spectral distribution of the given standard illuminant and the data of the color matching functions of the Standard Observer, which the device then combines through integrals to give the final result, or the strength of the spectral distribution of the light reflected by the various objects.

Calculation of Metamerism by spectrophotometer

In the previous unit, we described how the color of an object depends on the light source through which it is perceived.

Another problem related to the source of illumination is when the colors of two or more objects appear the same under one source of illumination - eg. under natural sunlight - but the opposite under another light source - e.g. under artificial interior lighting.

This phenomenon, when color perception changes under the influence of the light source, is called Metamerism.

For metameric objects, the color spectral reflectance characteristics of the two objects are different, but the resulting tristimulus values are the same under one illumination source, and different under another.

The most frequent cause of this problem is the use of different pigments or materials for dyeing.

Figures 24 and 25 illustrates the spectral reflection curve of two colored objects, where the difference can be immediately noticed.

However, the L*a*b* values for the measurements performed under the standard illuminant D65 are identical for the two objects (fig.24), while the values under the standard illuminant A are different (fig.25).

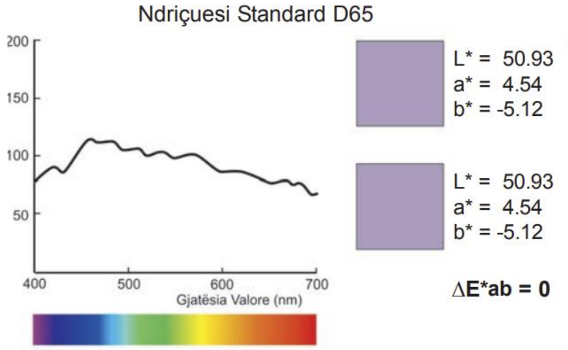

Figure 24 Spectral reflection curve of two colored objects under standard illuminator D65

This illustrates that even though the two objects have characteristics of different spectral reflectance, their colors will look the same under daylight (D65 standard lamp).

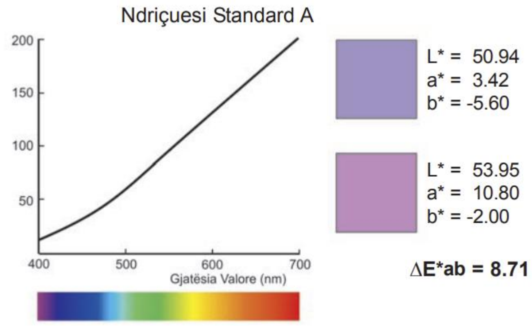

Figure 25 Spectral reflection curve of two colored objects under standard illuminator A. Source: Milot Gusia "Ngjyra, Teoria dhe Përdorimi Praktik", , 2013. ISBN: 978-9951-8825-1-4

Therefore, how should metamerism be noticed?

For evaluating metamerism, it is necessary that the measurement of the colors of the objects is performed at least under two or more standard lamps with a strength of different spectral distribution, such as illuminator standard D65 and Standard Illuminant A.

Although both tristimulus colorimeters and spectrophotometers use the same source of illumination independently, they can calculate the results based on the data they possess for the various luminaries in their memory.

Tristimulus colorimeters can do the math only for standard C illuminators and standard D65 illuminators, both of which feature natural lighting daily and have a similar strength of spectral distribution. Therefore, colorimeters cannot be used to assess metamerism.

On the other hand, spectrophotometers are equipped with the strength of the spectral distribution of a string of large of standard luminaries, so can easily define metamerism.

Furthermore, the spectrophotometers can show in their display the spectral reflectance graph of measured objects (fig.26), and hence offer an accurate illustration of the changes of spectral reflections of two or more colors.

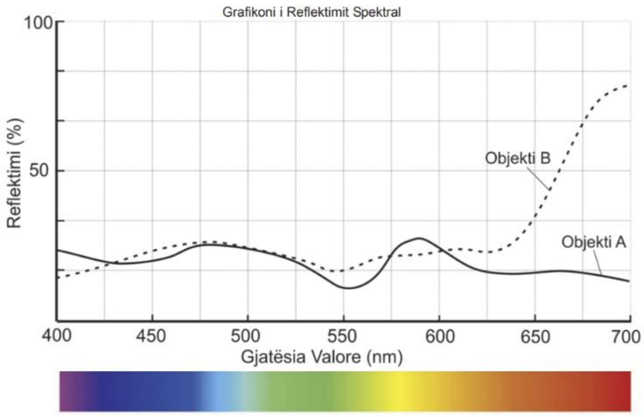

Figure 26 – The spectral reflectance graph of the two objects shown in the device display. Source: Milot Gusia "Ngjyra, Teoria dhe Përdorimi Praktik", , 2013. ISBN: 978-9951-8825-1-4

Characteristics of the Spectrophotometer

- The spectrophotometer has stored data for a large range of (CIE) Standard illuminants that enable measuring the color of objects in different lighting conditions.
- The data of the measurements are saved automatically at the exact time of execution of measurement.
- Measurement results can be displayed on the spectrophotometer display in the form of spectral reflectance graph.
- The viewing/illumination geometry is fixed to ensure constant and unchanging conditions for each measurement.
- The spectral sensor of the spectrophotometer consists of multiple segments that enable measuring light in each wavelength range thus providing great level of accuracy.
- Measurement data can be shown in numerical form in a large range of color spaces, including Yxy, L*a*b*, Hunter Lab, etc.
- Differences between colors can be measured and displayed immediately in numerical form or in the form of a spectral reflectance graph on the spectrophotometer display.

Discussion/Conclusion

The challenges of professional measurement of colors in various surfaces of design models through visual identification have made the accurate measurement and notation of colors difficult.

Perceived color is a matter of individual and subjective interpretation. Different individuals, even when looking at an identical color, based on different physiological abilities and individual experiences will express it in different ways.

Since there are many ways to express color, describing a particular color is extremely difficult and not objective. If we write a color like: "fiery red", can we expect others to imagine that color accurately? The verbal description of color is very complicated and difficult.

Color names have changed throughout history. For example, the color red has many names, such as: "vermilion", "cinnibar", "crimson", "pink", “strawberry", "scarlet" etc. These are considered the common color designations.

The influence of different ambient conditions in color perception, such as changes in the source of illumination, change of background, change in the light source direction and viewers individual sensitivity to colors, etc. has brought to different standards of color grading systems, such as Munsell, NCS, DIN, etc.

Although these systems can obtain a consistent and accurate color measurement, they are also very costly and cumbersome to use.

Measuring instruments, such as Colorimeters and Spectrophotometers can store data for a large range of (CIE) Standard illuminants that enable measuring the color of objects in different lighting conditions, and also the data of the measurements are saved automatically at the exact time of execution of measurement. The Measurement results are displayed on the spectrophotometer display in the form of spectral reflectance graph which gives a more comprehensive view of color qualities of designed objects. The spectral sensor of the spectrophotometer consists of multiple segments that enable measuring light in each wavelength range thus providing great level of accuracy. Measurement data are shown in numerical form in a large range of color spaces, including Yxy, L*a*b*, Hunter Lab, etc. Differences between colors can be measured and displayed immediately in numerical form or in the form of a spectral reflectance graph on the spectrophotometer display.

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