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Deformacija Ittnovega barvnega kroga v barvnih sistemih CIE L*a*b* in CIE xy

Izvirni znanstveni članek

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Izvleček

Znanstveniki se že stoletja ukvarjajo z naukom o barvah in postavljajo različne barvne sisteme, ki bi čim bolj realno pokazali postavitev barv v prostoru in razmike med posameznimi barvami. Med umetniki je zelo razširjena likovna teorija švicarskega umetnika Johannesa Ittna, ki je definiral kontrastne in harmonične barve in barvne sestave na osnovi dvanajstdelnega barvnega kroga in barvne krogle. Naše raziskovalno delo je temeljilo na Ittnovi teoriji.
Želeli smo ugotoviti, če imajo barvne harmonije tudi v CIE-barvnem prostoru kakšne skupne značilnosti in če lahko tudi v CIE-barvnem prostoru predvidevamo, katere barve so med seboj harmonične. Želeli pa smo ugotoviti tudi, ali likovna teorija velja, če jo prenesemo v CIE-barvni prostor, ki se uporablja predvsem za znanstvene namene. Ugotavljali smo, kakšne so značilnosti barvnih akordov, ki so lahko harmonični ali neharmonični, v CIE-barvnem prostoru in če jih lahko primerjamo z Ittnovimi ugotovitvami, po katerih si komplementarni barvi v barvnem krogu stojita nasproti, primarne, sekundarne in terciarne barve pa med seboj tvorijo trikotnik.

Ključne besede: barvna metrika, barvni prostor CIE Lab, diagram CIE xy, Ittnova barvna teorija, barvne harmonije, barvni akordi in barvni kontrasti

*Deformation of Itten's colour circle in colour systems CIE L*a*b* and CIE xy*

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Abstract

Scientists have been studying colours and colour harmonies for centuries and have tried to arrange them in different colour systems; which show the most real arrangement of colour in the space and spacing between them. Today, most artists follow colour scheme theory by Swiss painter Johannes Itten, who explained the contrasts and harmonies of colours with the help of the colour circle and colour sphere in his book The Art of Colour. His theory was also the basis of our research work.
The aim of this research was to find out how colour harmonies function in CIE-colour spaces – whether they share any common characteristics, and if it is possible to anticipate which colours are harmonious. We also wanted to find out the correctness of the art colour theory when transferred into CIE-colour space, which is primarily used for scientific purposes. We concentrated on the characteristics of colour accords, which can be harmonious or inharmonious, in the CIE-colour space, and the possibility of comparing them with Itten's theory, where complementary colours stand opposite to each other in the colour circle, while

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primary, secondary and tertiary colours form a triangle.

Key words: colorimetry, CIE – colour systems, CIE xy diagram, Itten's colour theory, colour harmony, colour contrasts.

1 Introduction

Scientists have been studying colours and colour harmonies for centuries. The first colour theory was developed by Leonardo da Vinci, who concluded that the most harmonic colours follow the spectral colours of the rainbow. He was the first who pointed out the meaning of opposite colours for composition of colour harmonies. [1, 2]

Today, artists are using different colour systems and collections of colours. Colour systems are systematically arranged colours and are mostly used for scientific purposes. Collections of colours are colours arranged after defined characteristics and are most commonly used for commercial purposes. Colour systems and colour collections are divided into different groups based on different characteristics.

Munsell's system was developed by the American painter Munsell in the beginning of twelfth century. Colours are divided into ten parts on a colour circle and are based on the principle of visually equal spaces between colours and on the principle of compensation, which means that colours which are located opposite to each other can be mixed in neutral grey colour.

The NCS (natural colour system), which was designed by Skandinavian Institute for colours, has been designed similarly to the Munsell's system. The NCS system is based on the presumption that human eye as pure colour detects the six basic colours: yellow, red, blue, green, white and black.

A system that also has visually equal spaces between colours is the OSA (Optical Society of America) system.

In industry, architecture, design, graphics, and fashion a professional colour system Pantone is being used. This system is based on rules of mixing colour lights, dyes and pigments. The Oswald's system, which is similar to the Pantone system, is adjusted to sensual perception.[2]

For colour evaluation nowadays, various systems are used which are based on the legalities

1 Uvod

Znanstveniki se že stoletja ukvarjajo z naukom o barvah in barvnih harmonijah. Prvi znani nauk o barvah je razvil Leonardo da Vinci, ki je sklepal, da so barvni sestavi, ki sledijo zakonitostim mavrice, najbolj harmonični in skladni. Prvi pa je pokazal tudi na pomen nasprotnih barv za nastanek barvnih harmonij. [1, 2]

Umetniki dandanes uporabljajo različne barvne sisteme in zbirke barv. Sistemi so sistematična razporeditev barv in se uporabljajo predvsem v znanstvene namene, zbirke barv pa so po določenih kriterijih razporejene barve, ki se uporabljajo predvsem v komercialne namene. Barvne sisteme in zbirke na osnovi določenih kriterijev delimo v različne skupine.

Munsllov sistem je na začetku dvajsetega stoletja razvil ameriški slikar Munsell. Barve so razvrščene v desetdelni barvni krog na principu enakih barvnih razmikov in na principu kompenzativnosti, kar pomeni, da nasproti ležeče barve lahko pomešamo v nepestro barvo.

Na podoben način je zasnovan tudi NCS – Natural Color System, ki ga je razvil skandinavski inštitut za barve in temelji na predpostavki, da človek zazna kot čiste barve šest osnovnih barv: rumeno, rdečo, modro, zeleno ter belo in črno.

Sistem z vizualno enakimi razmiki je tudi sistem OSA (Optical Society of America).

V industriji, arhitekturi, oblikovanju, grafiki in modi se uporablja profesionalni barvni sistem Pantone. Ta temelji na pravilih mešanja barvnih svetlob, barvil in pigmentov. Na podoben način je narejen tudi Ostwaldov sistem, ki je prilagojen čutni zaznavi. [2]

V današnjem času se za vrednotenje barve uporabljajo sistemi, ki temeljijo na zakonitostih, ki jih je opredelila mednarodna organizacija CIE (Commission Internationale de l'Eclairage) in so zelo pomembne za merjenje nastanka barve in njeno vrednotenje. CIE-sistemi temeljijo na teoriji, ki razlaga, da barvni dražljaj nastane s kombinacijo vira svetlobe, materije in opazovalca. CIE je definirala standardne vrste svetlob in standardnega opazovalca ter razvila metode za numerično vrednotenje barve. Zelo pomembni in velikokrat uporabljeni v znanosti so:

- barvni diagram CIE xy, ki je dvodimenzionalna predstavitev barv;
- sistem CIE L*a*b* ali CIELAB je najbolj uporabljan sistem v znanosti za numerično vrednotenje barve; definiran je kot sistem z enakimi prostorskimi razmiki;
- barvni sistem L*C*h* pa je zelo podoben CIELAB-barvnemu sistemu, le da so namesto pravokotnih uporabljene polarne koordinate. [3, 4]

Sistema, ki temeljita na CIE-zakonitostih, sta tudi RAL in DIN. RAL- sistem je leta 1993 predstavil RAL – nemški inštitut za kakovost in označevanje. V RAL-sistemu so razmiki med barvami definirani s CIELAB-formulami za barvne razmike. V DIN-sistemu so barve razporejene v barvno telo, z razmiki med barvnimi niansa-

made by the international organization CIE (Commission Internationale de l'Ècláirage), which are very important for colour measurement and colour evaluation. CIE-systems are based on a theory that explains that colour stimulus is a result of a combination of a light source, matter, and an observer. CIE has defined standard sources of light and standard observers, and has developed a method for the numerical evaluation of colours. The most frequently used in science and most important colour systems are:

- *CIE x,y colour diagram is a two dimensional presentation of colours.*
- *The most used colour system in science for numerical evaluation of colour is L*a*b* or CIELAB system. It is defined as a system with the same colour spaces between colours.*
- *L*C*h* - colour system is similar to the CIELAB colour system except that., that instead of rectangular coordinates, polar coordinates are used. [3, 4]*

The RAL-system and DIN-system are colour systems which are also based on CIE-legalities. The RAL-system was presented in 1993 by RAL – the German Institute for Quality Assurance and Certification. In the RAL-system, the spacing between colours is defined with CIELAB, which are equations for colour spacing.

In the DIN-system the colours are organized in a colour body with the same distance between colour shadows, which are perceived in the same way. On the basis of this colour system, a collection of colour was made: the result is the DIN – colour card. [2]

*All colour systems are, as models, little simplified and show an arrangement of colours in colour space. Artists and designers decide on colours on the basis of their emotional and visual perception; however, these bases are not reliable. With the evolution of the CIE L*a*b* system, the colours have started to be evaluated objectively. The objectivity of judgment of colour contrasts, colour harmony, and colour chord has increased in general, independent of subjective feelings.*

The objective evaluation of colour is useful in industry due to better understanding between manufacturer and costumers.

mi, ki so zaznavno enaki. Na osnovi izdelanega sistema je bila narejena zbirka barv, DIN-barvna karta. [2]

Vsi sistemi so kot modeli rahlo poenostavljeni in nam predstavljajo razporeditev barv v prostoru. Oblikovalci se o barvah odločajo predvsem na osnovi subjektivnih občutkov, vendar le-ti niso zanesljivi. Z razvojem CIE L*a*b*-sistema se je začelo barve vrednotiti objektivno. Tako se je povečala tudi objektivnost presojanja barvnih kontrastov in harmonij ter barvnih akordov nasploh, neodvisno od subjektivnih občutkov. Objektivno vrednotenje barve je zelo zaželeno v industriji zaradi lažjega sporazumevanja med proizvajalci in naročniki.

V prispevku bomo poskušali bolj objektivno, s pomočjo CIE L*a*b*-sistema in CIE xy-barvnega diagrama, oceniti barvne harmonije in kontraste ter teorijo švicarskega slikarja Johannesa Ittna, ki je barvne harmonije in kontraste razložil v svoji knjigi Umetnost barve, to pa še danes upošteva večina umetnikov in likovnih teoretikov. Ittnova teorija je razvita za uporabo v slikarstvu in temelji predvsem na čutni in vidni zaznavi. [4] Tako bi lahko rekli, da je namen našega raziskovalnega dela likovno teorijo, ki temelji predvsem na čutni in vizualni zaznavi, ovrednotiti z merljivimi parametri in številkami, ki jih ponujata CIE L*a*b*-sistem in CIE xy-barvni diagram.

2 Teoretični del

2.1 O Ittnu in njegovi teoriji

Itten se je pri razvijanju barvne teorije opiral na Goetheja in Rungeja. Po Goetheju je povzel idejo o barvnem krogu, po Rungeju geometrijski model barvne krogle.

Barvni krog je sistem razporeditve barv na dvanajst barvnih ploskev. Temelji na subtraktivnem mešanju barv. Osnovne barve rumena, rdeča in modra z medsebojnim mešanjem tvorijo sekundarne barve oranžno, zeleno in vijolično. Z mešanjem primarnih in sekundarnih barv dobimo terciarne barve rumenooranžno, rdečeoranžno, rdečevijolično, modrovijolično, modrozeleno, rumenozeleno. Primarne, sekundarne in terciarne barve med seboj tvorijo enakostranične trikotnike.

Na barvni krogli je možno nazorno prikazati povezave med črno in belo barvo ter drugimi barvami. Čiste barve so razporejene v ekvatorialnem pasu. Na polih sta črna in bela barva. V sredini krogle poteka siva lestvica med belim in črnim poltonom. Med tečajem in ekvatorjem so posvetljene oziroma potemnjene barve. [5, 6]

2.2 Harmonija barv

Kadar govorimo o harmoniji barv, ocenjujemo skupni učinek dveh ali več barv. Harmonija pomeni ravnotežje, simetrijo moči, pomeni skladnost in ubranost določene skupine barv, ki naj bi na opazovalca vplivala ugodneje kot kaka druga barvna kombinacija. Na splošno ločimo dve vrsti harmonije:

*In this article, we will try to evaluate colour harmonies and colour contrasts more objectively with the help of the CIE L*a*b* system and CIE xy colour diagram, and the theory of the Swiss painter Johannes Itten, which is explained in his book The Art of Colour which is used by a major part of artists and artist theoretics. Itten's theory has been developed for use in the art of painting and is based on emotional and visual perception. [4] It could be said that the purpose of our research work is to evaluate art theory that is based on emotional and visual perception, with measurable parameters and numbers which are offered by the CIE L*a*b* system and CIE xy colour diagram.*

2 Theoretical part

2.1 Itten and his theory

When Itten was developing his colour scheme theory, he based it on Goethe and Runge, where he adapted the idea of the colour circle from Goethe and the geometric model of the colour sphere from Runge.

The colour circle is divided into twelve parts and is based on a subtractive mixing of colour. By mixing the primary yellow, red, and blue, the colours secondary orange, green and purple are produced. By mixing primary and secondary colours, we get tertiary yellow-orange, red-orange, red-purple, blue-purple, blue-green and yellow-green. Primary, secondary, and tertiary colours form equilateral triangles, as can be seen on Figure 1.

With the colour sphere, the connections between black and white colour and other colours can be easily demonstrated. Pure colours are arranged in the equatorial belt, with black and white colour positioned on the poles, lightened or darkened colours are between the poles and the equator, and the grey colour scale is in the centre of the sphere. [5, 6]

2.2 Colour harmony

When speaking of colour harmony, we speak of the joint effect of two or more colours. Harmony means balance, symmetry of intensity, and harmony of a certain colour group, which is supposed to have a more pleasant effect on the observer than any other combination of colours.

Figure 1: IItten's colour circle. [5]

- harmonija na osnovi sorodnosti (podobnosti, analogije);
- harmonija na osnovi kontrastnih odnosov, kamor sodi tudi harmonija komplementarnih odnosov.

Harmonija sorodnih barv lahko označuje barvno skupino, v kateri so si barve sorodne po barvitosti in v barvnem krogu ležijo blizu druga druge. Tako lahko nastane npr. harmonija toplih ali hladnih barv. Barve so si lahko sorodne po svetlosti, npr. harmonija svetlih barv, harmonija temnih barv, ali po nasičenosti.

Itten je menil, da so barve, ki temeljijo na harmoniji na osnovi kontrastnih odnosov, harmonične tedaj, ko pomešane med seboj ustvarjajo nevtralno sivo barvo. Mislil je, da so harmonične vse komplementarne barvne dvojice in vse tiste barve, ki v barvnem krogu tvorijo enakostranični ali enakokraki trikotnik, in tudi vse druge kombinacije barv, ki z mešanjem povzročijo nastanek nevtralne barve. Tako je ustvaril harmonije (barvne akorde) kontrastnih barv in jih glede na število barv razdelil na dvozložne barvne akorde ali diade, trizložne barvne akorde ali triade, štirizložne barvne akorde ali tetrade, petzložne barvne akorde ali pentade ter šestzložne barvne akorde ali heksade.

- Dvozložni barvni akordi ali diade: v dvanajstdelnem barvnem krogu sta dve nasprotni si barvi komplementarni in tvorita harmonično dvozvočje (rdeča – zelena, modra – oranžna, rumena – vijolična), slika 2.
- Trizložni barvni akordi ali triade: kombinacije barv, ki v barvnem krogu tvorijo enakostranični trikotnik (oranžna – vijolična

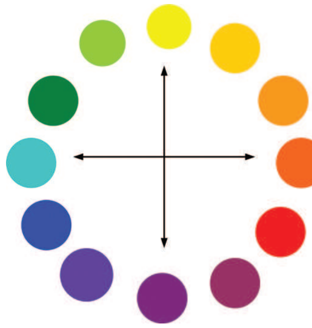
In general, we speak of two types of harmony:

- *harmony, based on affinity (similarities, analogies)*
- *harmony, based on contrast relations, including harmony of complementary relations*

Harmony of related colours can indicate a group of colours that are related by colouring and placed close to each other in the colour circle. In such a way, a harmony of warm or cold colours is formed. Colours can be related by lightness (e.g. a harmony of light or dark colours) or by saturation.

According to Itten, colours are harmonious when they form a neutral grey colour via mixing. He believed that all complementary colour pairs and all the colours which form an equilateral or an isosceles triangle in the colour circle, as well as all other colour combinations (which, by mixing, result in a neutral colour), are harmonious. That way, he created the contrast colour harmonies or contrast colour chords and divided them, according to the number of colours, into dyads or two partial colour chords), triads or three partial colour chords, tetrads or four partial colour chords, pentads or five partial colour chords and hexads or six partial colour chords.

- *Dyads or two partial colour chords: two opposite colours in the twelve-part colour circle are complementary and harmonious (red – green, blue – orange, yellow – purple), Figure 2.*
- *Triads or three partial colour chords: combination of colours that form an equilateral triangle in the colour circle (orange-purple-green, yellow-orange – red-purple – blue-green, red-orange – blue-purple – yellow-green), Figure 3.*
- *Tetrads or four partial colour chords: formed by two pairs of complementary colours of the twelve-part colour circle. In the colour circle they form a square or a rectangle, which can be arbitrarily rotated (yellow – orange-red – purple – blue-green, yellow-orange – red – blue-purple – green, orange – purple-red – blue – yellow-green), Figure 4.*
- *Hexads or six partial colour chords: formed by drawing a hexagonal, which comprises three double complementary pairs, in the colour circle (yellow – orange – red – purple – blue – green, yellow-orange – red-orange*



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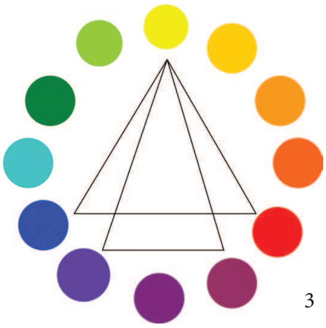

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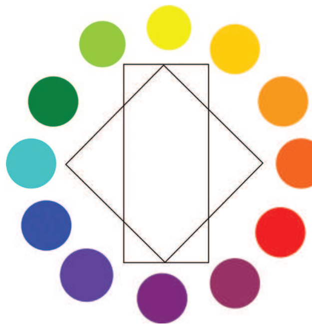

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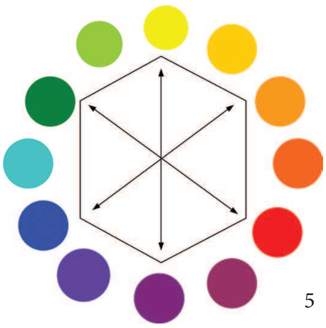

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Figure 2: Dyads or two partial colour chords.
Figure 3: Triads or three partial colour chords.
Figure 4: Tetrads or four partial colour chords.
Figure 5: Hexads or six partial colour chords.

– zelena, rumenooranžna – rdečevijolična – modrozelena, rdečeoranžna – modrovijolična – rumenozelena), slika 3.

- Štirizložni barvni akordi ali tetrade nastanejo z dvema dvojicama komplementarnih barv iz dvanajstdelnega barvnega kroga. V barvnem krogu tvorijo kvadrat ali pravokotnik, ki ga lahko poljubno obračamo (rumena – oranžnordeča – vijolična – modrozelena, rumenooranžna – rdeča – modrovijolična – zelena, oranžna – rdečevijolična – modra – rumenozelena), slika 4.
- Šestzložni barvni akordi ali heksade nastanejo z vrisom šesterokotnika, ki ga dobimo s pomočjo treh dvojnih komplementarnih dvojic, v barvni krog (rumena – oranžna – rdeča – vijolična – modra – zelena, rumenooranžna – rdečeoranžna – rdečevijolična – modrovijolična – modrozelena – rumenozelena), slika 5. [5]

3 Eksperimentalni del

Raziskovanje barvnih harmonij je temeljilo na dvanajstdelnem barvnem krogu. Vsaka barva je razdeljena na osem barvnih odtenkov, ki se med seboj razlikujejo po svetlosti. Barvne vrednosti barv so bile podane z barvnimi vrednostmi CMYK (Cyan, Magenta, Yellow, blacK).

– red-purple – blue-purple – yellow-green), Figure 5. [5]

3 Experimental part

Colour harmonies research is based on the twelve-part colour circle. Each colour is divided into eight shades, which differ in lightness. The colour values are given in terms of CMYK (Cyan, Magenta, Yellow, and blacK) colour values.

3.1 Colour measurements

In spite of the already known CMYK colour values, in the book Barvna harmonija 2 (color harmony 2), priročnik za ustvarjanje barvnih kombinacij [7] (where all the researched colours are given), we measured the colours again with the spectrophotometer Eye-One by Gretag Macbeth. We applied a standard light source D65, the measuring angle was 2° and the measuring geometry 45/0. We measured colour values L, a*, b*, C* and h, as well as X, Y, Z. From the latter, we calculated the x, y and z values. For each colour, four measurements were made and the average value and standard deviation were calculated.*

*With the help of measured colour values, we determined the characteristics of colour chords in the CIE-colour space. We tried to find out the differences between monochromatic colour chords, two partial colour chords of complementary colours (red-green, orange-blue, yellow-purple), three partial colour chords or triads (primary, secondary and tertiary colours), and colour chords of analogue colours (red, yellow and blue), as introduced by Itten. We also tried to determine how these colours are arranged in the CIE L*a*b* and xy diagram. In addition, we compared lightness, purity, and hue.*

*We decided to present colour chords in the CIE L*a*b* colour system because this system describes colours as the most harmonized, thus abolishing differences between reproductive colours and differences between different calibration monitors and output devices. The CIE L*a*b* system is larger than the CMYK model, which is used in printing, and therefore occupies and describes all colours of the CMYK model. At conversion from CIE L*a*b to other models, colours do not change if the colours*

3.1 Merjenje barv

Kljub že podanim CMYK-barvnim vrednostim v knjigi Barvna harmonija 2, priročnik za ustvarjanje barvnih kombinacij [7], kjer so bile navedene vse preiskovane barve, smo barve še enkrat izmerili s spektrofotometrom Eye-One podjetja Gretag Macbeth. Za merjenje je bil uporabljen standardni vir svetlobe D65, kot merjenja je bil 2° in geometrija merjenja 45/0. Izmerjene so bile barvne vrednosti L*, a*, b*, C*, h ter X, Y, Z; iz teh vrednosti so bile izračunane še vrednosti x, y in z. Za vsako barvo so bile narejene štiri meritve, izračunana sta bila povprečna vrednost in standardno odstopanje.

S pomočjo izmerjenih barvnih vrednosti je bilo ugotovljeno, kakšne so lastnosti barvnih akordov v CIE-barvnem prostoru. Ugotavljali smo, kakšne so razlike med monokromatičnimi barvnimi akordi, dvozložnimi barvnimi akordi komplementarnih barv – diadami (rdeče-zelena, oranžno-modra, rumeno-vijolična), trizložnimi barvnimi akordi – triadami (primarnih, sekundarnih in terciarnih barv) ter barvnimi akordi analognih barv (rdeče, rumene in modre barve), kot jih je predstavil Itten. Ugotavljali smo, kako so te barve razporejene v CIE L*a*b* in xy-diagramu. Med seboj smo primerjali tudi svetlost, kromo in barvni ton.

Za predstavitev barvnih harmonij na CIE L*a*b* smo se odločili zato, ker ta sistem najbolj usklajeno opisuje barve, odpravlja razlike med reprodukcijskimi barvami in razlike pri različni kalibraciji monitorjev in izhodnih naprav. Po obsegu je večji kot CMYK-model, ki se ga uporablja predvsem v tiskarstvu, zato lahko zavzame in opiše vse njegove barve. Barve se pri pretvorbi iz L*a*b* v druge modele ne spreminjajo, če se ujemajo s paleto tiskalnika. [8]

CIE xy-diagram smo uporabili zato, ker nam barve, ki ležijo v notranjosti spektralne črte in črte škrlata, predstavljajo vse realne barve. S pomočjo xy-diagrama smo lahko tudi ugotovili, katerih barv CMYK-model ne more sproducirati. Ugotovili smo tudi, kako Ittnove barvne harmonije ležijo v diagramu realnih barv.

Barvni toni, ki smo jih izmerili, niso popolnoma identični barvnim tonom, ki jih je uporabil Itten v svoji teoriji, saj smo izmerili reprodukcije barv, ki niso popolnoma enake originalu, in pri vsaki reprodukciji pride do manjših ali večjih napak.

Zavedamo se, da popolne natančnosti ni mogoče doseči, saj je barvno dojemanje odvisno od materiala, na katerem je barva natisnjena, od stroja, s katerim barvo tiskamo, načina tiskanja. Z svojim raziskovalnim delom smo poskušali objektivno primerjati barvne akorde med seboj. Lahko trdimo, da bi dobili zelo podobne rezultate, tudi če bi bile barve rahlo spremenjene, le da bi bili koti med posameznimi barvnimi toni rahlo drugačni.

4 Rezultati z razpravo

4.1 Monokromatični barvni akordi

Monokromatični barvni akordi so barvne kombinacije, v katerih je ena barva uporabljena v kombinaciji z enim ali več svojimi odten-

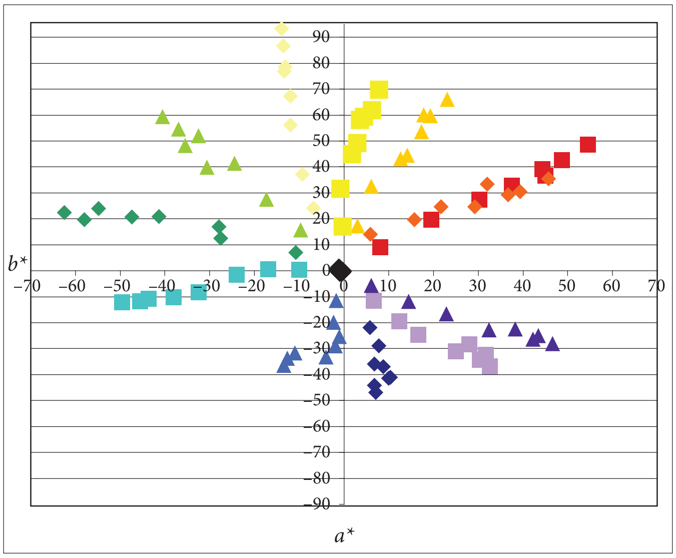
correspond with the pallet of the printer. [8]
The CIE xy diagram was used because all the colours which lie inside of the spectral line and line of scarlet present all real colours. With the help of the xy diagram, the colours which the CMYK model cannot produce have been determined. The research also brought us the knowledge of how Itten's colour chords lie in the diagram of real colours.
Colour shades which have been measured, are not completely identical to the colour shades which Itten used in his theory, because the reproduction of colours was measured so that they are not completely identical to original. Smaller or larger mistakes occur at every reproduction.
We are aware that is not possible to achieve perfect accuracy because colour perceptions depend on the material on which the colour has been printed, from the machine with which colour has been printed, and on the way of printing. With our research, we try to objectively compare colour chords between themselves. We also claim that, if the colours are slightly changed, we will get similar results; only the angles between individual colours colour shades would be slightly different.

4 Results and discussion

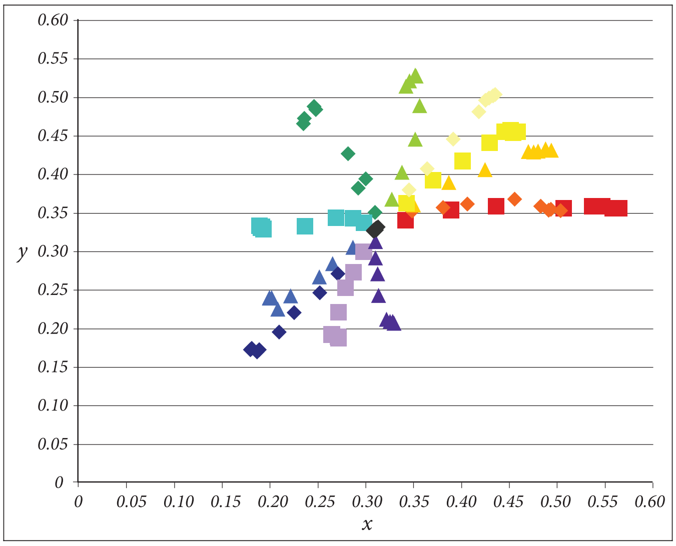
4.1 Monochromatic colour chords

Monochromatic colour chords are colour combinations where one colour is used in the combination with one or more of its shades. We could say that shades of one colour in the colour circle form monochromatic colour chords. We used this approach on every one of the twelve colours, each having eight shades, which differ in lightness and saturation or colour purity. This tells us how much black colour they include and what the distance from black-white axle is.
According to the first colour hue, the lightness was increasing; every next shade had a higher L value. The lightest colour was the citron yellow, with its L* = 65.13, and the darkest purple-blue, with L* = 26.53. These findings are in complete accordance with the colour theory.*
When analysing colour saturation or purity of colour, we found that the purest colours are those without the component K in the CMKY model. The purity of the shades of grey is almost

ki. Tako bi lahko rekli, da barvni odtenki ene barve barvnega kroga med seboj tvorijo monokromatične barvne akorde. Tako smo obravnavali vseh dvanajst barvnih tonov, vsak barvni ton je imel še osem različnih odtenkov, ki so se med seboj razlikovali po svetlosti in kromi oziroma barvni čistosti, ki nam pove, koliko nepestre barve vsebuje odtenek in kolikšna je oddaljenost od črno-bele osi. Svetlost se je glede na prvi barvni ton povečevala, vsak naslednji odtenek je imel večjo vrednost L*. Pokazalo se je, da je najsvetlejša barva citronsko rumena, ki ima L* 65,13, in najtemnejša modrovijolična, ki ima L* 26,53, kar se popolnoma ujema z barvno



Figute 6: a and b* values of all colours.*



Figute 7: x and y values of all colours.

unchangeable and stays around 0. All twelve colours had almost a constant hue, as shown in the Figure 6 and Figure 7.

*In the a**, *b** *(Figure 6) and the xy diagram (Figure 7), the colours progress in the same way as in the colour circle (or the colour created in the CMKY colour model). The angles between the contiguous colours are not the same as in Itten's colour circle. There is an especially big difference (70°) in the angle between red and purple, as red lies at an angle of 40° and purple at 330°.*

The smallest difference in the angles is between red and orange-red. As it can be seen from the Figures 6 and 7, the angles are also small between other colours, which can be connected with the disadvantage that some colours are printed. So, it could also be claimed that some colours are inappropriately chosen in the basis of the colour atlas itself.

Itten's colour theory can be blamed for the big colour difference between adjacent colours. Colour theoreticians have found that, if Itten's instruction on how to make the colour circle from primary colours, yellow, red and blue, which are put on the corners of equilateral triangle, are used, colours cannot be pure, rather, the result is mixed colours. Itten's yellow is a bit reddish; his yellow is a mixture of the fundamental colours magenta-red and orange-red. His blue is a mixture of the fundamental colours purple-blue and cyan-blue. If Itten's instructions are followed, the mixing of primary colours should lead to the creation of pure orange, green and purple but, instead of the promised purple colour which is mixed is a dark, dirty purple looking like brown; mixed green is dirty and dark. Only orange can be mixed from reddish yellow and yellowish red.

It cannot be easily understood why he persisted at this incorrect presumption, especially because he himself did not use the "primary colours yellow, red and blue," which are suggested by him, at the printing of his own book. Also, he did not allow other colour shades to occur by mixing primary colours. Instead, he used six printing inks (yellow, red, blue, purple, green and orange), since it was impossible, even with the clearest printing inks, to achieve the results which were given in his instructions. [9, 10]

teorijo. Če pogledamo vrednost C* (kromo) oziroma barvno čistost, se pokaže, da so najbolj čiste tiste barve, ki v CMYK-modelu nimajo primešane komponente K, črne barve oziroma krome. Sivim odtenkom se kroma oziroma barvna čistost ne spreminja in je okrog 0.

Vseh dvanajst barv je imelo ne glede na barvni odtenek skoraj konstanten barvni ton, saj enake barve ležijo na eni premici, kar se vidi tudi s slik 6 in 7.

V diagramu a*, b* (slika 6) in diagramu xy (slika 7) si barve sledijo ena za drugo enako kot v barvnem krogu oziroma na barvni lestvici, narejeni v CMYK-barvnem modelu. Koti med sosednjimi barvami niso enaki tako kot v Ittnovem barvnem krogu, kjer so barve med seboj oddaljene za 30°. Velika razlika je v kotu med rdečo in vijolično, kar 70°, saj leži rdeča barva pri h je 40°, vijolična pa pri h 330°. Minimalna razlika med koti je med rdečo in oranžnordečo barvo. S slik 6 in 7 je razvidno, da so koti majhni še med nekaterimi drugimi barvami, kar lahko tudi povežemo z nezmožnostjo tiskanja nekaterih barv, lahko pa bi rekli, da so barve v barvnem atlasu že v osnovi tudi izbrane neprimerno.

Za velike razlike med sosednjimi barvami v neki meri lahko krivimo tudi samo Ittnovo teorijo. Barvni teoretiki so ugotovili, da ob upoštevanju Ittnovih napotkov, kako izdelati barvni krog iz osnovnih barv rumene, rdeče, modre, ki so postavljene na oglišča enakostraničnega trikotnika, te izhodiščne barve nikakor ne morejo biti čiste, ampak so že mešanice. Ittnova rumena je nekoliko rdečkasta. Njegova rdeča je mešanica osnovnih barv magentardeče in oranžnordeče. Njegova modra je mešanica osnovnih barv vijoličnomodre in cianmodre. Po Ittnovih navodilih naj bi iz teh izhodiščnih barv nastale z mešanjem čista oranžna, čista zelena in čista vijolična barva. Če sledimo njegovim navodilom, dobimo namesto obljubljene vijolične neko temno, umazano, vijolični podobno rjavo in tako zmešana zelena je umazana in temna. Le oranžno lahko nekako približno zmešamo iz rdečkastorumene in iz rumenkastordeče.

Nerazumljivo je, zakaj je Itten vztrajal pri teh napačnih predpostavkah, še posebej zato, ker pri tisku svoje knjige ni uporabljal „osnovnih barv rumene, rdeče in modre", ki jih je prej sam predlagal, in tudi ni dopustil, da bi nastale druge barvne nianse z mešanjem le-teh; namesto njih je uporabil šest pestrih tiskarskih barv: rumeno, rdečo, modro, vijolično, zeleno in oranžno. Celo z najčistejšimi tiskarskimi barvami namreč ni bilo mogoče doseči rezultatov, ki jih je napovedoval v svojih navodilih. [9, 10]

Izmerjene barvne vrednosti x in y ležijo v notranjosti xy-diagrama, saj CMYK-barvni model zavzema le približno tretjino vseh barv iz spektra bele barve. Na spektralni črti, ki ima obliko podkve, ležijo čiste spektralne barve, ki jih je na papirju nemogoče dobiti. Rdeča in rumena barva se približujeta spektralni črti, medtem ko je pri zeleni barvi primanjkljaj barv proti vrhu podkve zelo velik.

Na grafu a*, b* (slika 6) opazimo, da barve v prvem in drugem kvadrantu (rdeča, rumena, zelena) zavzemajo večje vrednosti kot v tretjem in četrtem kvadrantu koordinatnega sistema, kjer sta mo-

CMKY colour model covers only about a third of all white spectrum colours. The measured colour values lie in the inside of the xy diagram. On the spectral line there are pure spectral colours, which cannot be seen on paper; the red and the yellow are approaching the spectral line, and the green shows a great deficiency of colours towards the top of the horseshoe.

The graph a, b* (Figure 6) shows that colours with higher values lie in the first and second quadrant (red, yellow, green) and not in the third and fourth quadrant of the system of coordinates (blue, yellow). The highest a* value of the red is approximately 60 and the a* value of the green, which is furthest away from the coordinate system origin, is around –65. The b* values of yellow are up to 90, and the b* values of the blue are only up to –45. The biggest differences are on the b* axis.*

4.2 Harmonic two – colours colour chords

According to Itten's theory, the complementary colours in the colour circle lie opposite to each other (Figure 2). If we put complementary colours in the a, b* diagram, we see that they lie in opposite quadrants of the graph (Figures 8, 10 and 12). In the colour harmony of red and green, red is in the first and green is in the second quadrant (Figure 8); orange is in the first and blue is in the third quadrant (Figure 10); yellow is in the second and purple is in the forth quadrant (Figure 12). The reason for this originates from geometry and the setting up of the colours on the a* and b* axle, where a* is the red-green axle and b* is the yellow-blue axle. The completely pure colours are located on the a* and b* axles. These colours are very difficult to achieve with printing because smaller or larger mistakes can occur. The colours dealt with were not so carefully chosen.*

The distance is the largest between the purest colours; the lower the purity, the closer they are. That means that the a and b* values are decreasing.*

When studying colour harmony, the most important factor is colour hue, not the lightness or chroma of colours. Regardless of the lightness or chroma, the chosen colours share the same hue.

If we compare colour shades, we see that colours are not exactly opposite to each other, and their

dra in vijolična barva. Največja a*-vrednost rdeče barve je približno 60° in b*-vrednost okrog 50°, od koordinatnega izhodišča najbolj oddaljena zelena barva ima a* okrog –65° in b*-vrednost okrog 20°. Rumena barva zavzema b*-vrednosti do 90° in a*-vrednost okrog –15°, medtem ko modra barva dosega b*-vrednosti le do –45° in a*-vrednost okrog 15°. Kot je opazno, so velike razlike predvsem na b*-osi.

4.2 Dvozložni barvni akordi – diade

Po Ittnovi teoriji si komplementarne barve v barvnem krogu stojijo nasproti (slika 2). Če izbrane komplementarne barve postavimo v a*, b*-diagram (slike 8, 10, 12), opazimo, da barve stojijo v nasprotnih kvadrantih grafa. V barvnem akordu rdeče in zelene barve (slika 8) leži rdeča barva v prvem kvadrantu, zelena v drugem. V barvnem akordu oranžne in modre barve (slika 10) leži oranžna barva v prvem kvadrantu in modra v tretjem kvadrantu. Pri komplementarnem paru rumena in vijolična (slika 12) leži rumena barva v drugem kvadrantu, vijolična pa v četrtem, kar izvira iz geometrije in postavitve barv na oseh a* in b*, saj je a* rdeče-zelena os in b* rumeno-modra os. Na oseh a* in b* so bile popolnoma čiste barve. Vendar pa je te barve s tiskanjem težko doseči, saj prihaja do manjših in večjih napak. Barve, ki smo jih obravnavali, niso bile tako natančno izbrane.

Čisti barvi sta med seboj najbolj oddaljeni, z zmanjševanjem čistosti se barvi približujeta, kar pomeni, da se vrednosti a* in b* zmanjšujeta.

Za ugotavljanje razmerij in postavitve barv v barvnem prostoru je pomemben barvni ton, ne svetlost ali kroma barv, saj imajo izbrane barve ne glede na svetlost ali čistost barve enak barvni ton.

Če primerjamo barvne tone, ugotovimo, da si barve ne ležijo popolnoma nasproti, njihov kot ni 180°, kar lahko vidimo na sliki 14. Med rdečo in zeleno barvo je kot 110°, med oranžno in modro kot 185° ter med rumeno in vijolično kot 155°. Za take razlike med komplementarnimi barvami lahko krivimo tudi geometrijsko neenakost CIE L*a*b*- oziroma L*C*h-sistema v primerjavi z barvnim krogom oziroma barvno kroglo. Del krivde lahko pripišemo tudi Ittnovi teoriji in njegovim mešanicam barv, kot je opisano že zgoraj, ter tudi naši izbiri barv, ki so prikazane v barvnem atlasu, in natančnosti reprodukcije barv.

Če komplementarne barve postavimo v xy-diagram (slike 9, 11, 13), ugotovimo, da si barve ležijo nasproti. Tudi v xy-diagramu sta najčistejši barvi med seboj najbolj oddaljeni in najbližje spektralni črti, nečiste barve se med seboj približujejo in se pomikajo proti nepestri točki, točki 0.

To nam pokaže, da si komplementarne barve ležijo nasproti ne glede na to, v kakšnem barvnem prostoru oziroma sistemu jih opazujemo. Komplementarne barve so si nasprotne v barvnem krogu, kot trdi Itten, v diagramu CIE L*a*b* ležijo v nasprotnih ali sosednjih kvadrantih – glede na to, katero dvojico barv izberemo. Tudi v xy-diagramu si komplementarne barve ležijo nasproti.

*angles are not 180°. The angle between red and green is 110°, that between orange and blue is 185°, and that between yellow and purple is 155°. The reason for such differences among the complementary colours could also lie in the geometric inequality of the CIE L*a*b* or L*C*h* system in comparison to the colour circle or colour sphere, as shown in Figure 14.*

For these results, we can equally blame Itten's colour theory and his colour mixture (as it is

V našem primeru bi sicer lahko rekli, da je rumena barva, ki smo jo uporabili v barvnih akordih, rahlo rumenozelena, rdeča je rdečeoranžna, zelena je sicer skoraj zelena, vendar ima še malo primesi rumenkaste, uporabljena modra barva je rahlo modrozelena in vijolična je modrovijolična. Vse to lahko razberemo s slik 14 in 15. Iz navedenega si lahko tudi razložimo, zakaj so koti tako med dvokot tudi trizložnimi barvnimi akordi tako različni. Predpostavimo lahko, da bi lahko dosegli precej lepše rezultate, če bi izbrali bolj čiste barve, vendar smo se držali barv, natisnjenih v atlasu.

Popolnih harmonij – takih, kot jih opisuje Itten – v nobenem pri-

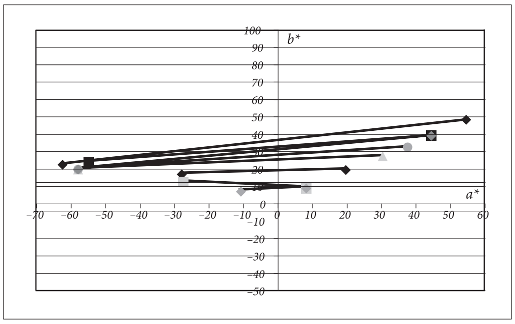


Figure 8: Red-green colour chord in a, b* diagram.*

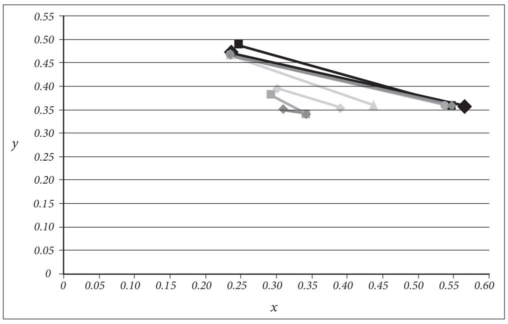


Figure 9: Red-green colour chord in xy diagram.

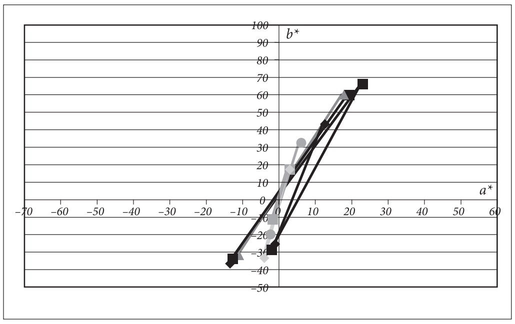


Figure 10: Orange-blue colour chord in a, b* diagram.*

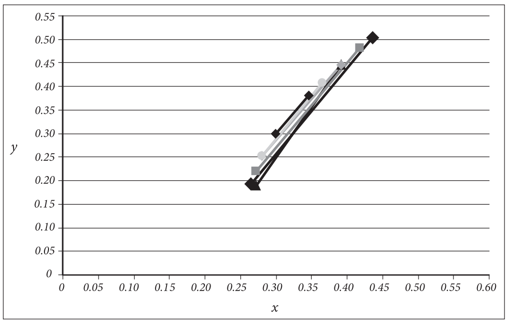


Figure 11: Orange-blue colour chord in xy diagram.

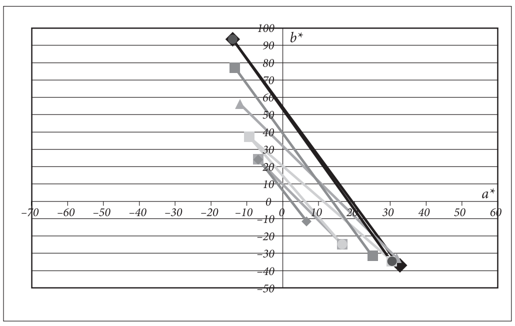


Figure 12: Yellow-purple colour chord in a, b* diagram.*

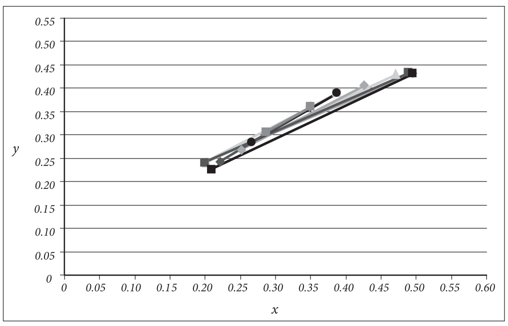


Figure 13: Yellow-purple colour chord in xy diagram.

described above), our choice of colour (which is shown in the colour atlas), and also the accuracy of the reproduction of colour.

If we put the complementary colours in the xy diagram (Figures 9, 11 and 13), we see that the colours are opposite to each other according to the colours in the xy diagram. The largest distance is between pure colours, and they are the closest to the spectral line; the lower the purity, the closer they are.

*This shows that complementary colours are opposite to each other, no matter which colour space they are observed in. Complementary colours lie opposite to each other in the colour circle, as Itten claimed; in the CIE L*a*b* colour diagram, colours lie in opposite or adjacent quadrants, depending on which colour pair we chose; complementary colours in the xy diagram also lie opposite to each other.*

In our case, it could be said that the yellow colour that is used in colour chords is a slightly yellow-green, red is red-orange, green is almost pure green with a bit of yellow, the blue is slightly blue-green, and purple is blue-purple. All this can be seen from Figures 14 and 15.

Given what has been mentioned so far everything, it can be understood why the angles between two and three colour chords are so different. It can be presumed that, if more pure colours could be chosen, much better results could be achieved. But, we have used the printing colour from the colour atlas.

Perfect colour harmonies, as described by Itten, are impossible to achieve, because, in practice, his theory does not have any real support and, as we already mentioned for the printing of his book, Itten used six printing inks: yellow, red, blue, purple, green and orange. [9]

4.3 Harmonic three – colours colour chord

*According to Itten's theory, the triads form equilateral triangles, which can be arbitrarily rotated (Figure 3). The strongest triad is the combination of primary red, yellow and blue, followed by secondary orange, green and purple, and tertiary red-orange, green-yellow and blue-purple colours. As shown in Figures 17, 19 and 21, colours form triangles in the CIE L*a*b* colour space, but they are not equilateral. As with the harmonic two-colour chords, every colour in the*

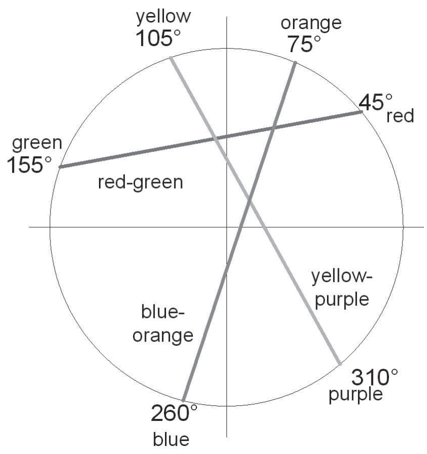


Figure 14: Harmonic two-colour chords.

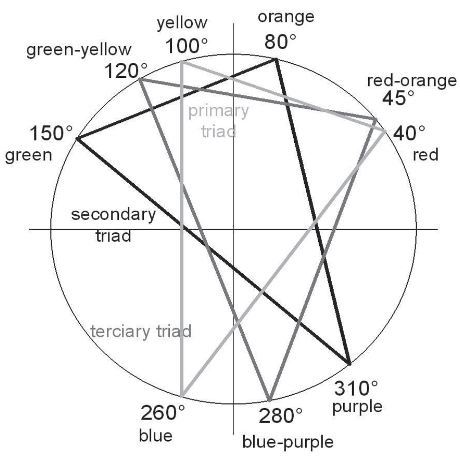


Figure 15: Harmonic three-colour chords.

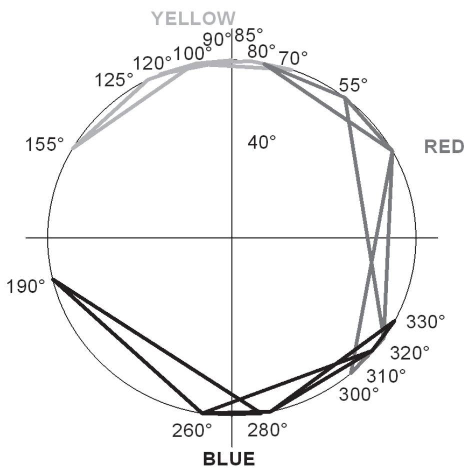


Figure 16: Harmonic analogue colour chords.

a, b* diagram lies in its own quadrant. Another similarity with harmonic two-colour chords is with pure colours; the purest colours are the furthest away from each other, as less pure colours are closer to each other. The lower the purity and lightness, the closer they are to the coordinate system origin and to each other. The a* and b* values decrease with purity. This holds for all three three-colour chords in Figures 17, 19 and 21.*

*Even though the CIE L*a*b* system is defined as a system with equal spatial distances, the geometric distances are not perceived as such. The triangles are not equilateral because the visual perception of colours in the CIE L*a*b* system is not the same. The situation is similar in the xy diagram (Figures 20, 21 and 22), where the colours are arranged with additive mixings of colours and the distances between colours in the two-dimensional diagram are visually not the same.*

Partly-incorrectly-chosen colours and colours chosen by Itten can be blamed for this results. If colours would be chosen a little differently, different angles between colours could appear, but the difference wouldn't be essential. Under no condition in CIE-colour space could equilateral triangles be achieved.

Similar to the CIE-colour space, the three-colour chord also form triangles in the xy diagram, but the triangles are not equilateral. As can be noticed, the pure primary, secondary, and tertiary colours make the biggest triangle, while all other combination are inside of this triangle, as can be seen on Figures 18, 20 and 22.

*In the CIE L*a*b* system and the xy colour diagram, it can be observed that primary colour triangles become smaller from pure colour to less pure. For tertiary colours, the size of triangles stays the same, which means that the purity of the colour does not reduce. Tertiary colours are already mixtures and are not as pure as the primary colours yellow, red and blue.*

Individual colours have almost the same colour shades (h) as two-colour chords. If we compare colour shades, we see that red and yellow form an angle of 60°, yellow and blue form an angle of 160°, and blue and red form an angle of 140°. Secondary orange and green form an angle of 70°, green and purple form an angle

meru ne bi dobili, saj njegova teorija v praksi nima prave podpore in je Itten pri tisku svoje knjige uporabil šest tiskarskih barv: rumeno, rdečo, modro, vijolično, zeleno in oranžno. [9]

4.3 Trizložni barvni akordi – triade

Po Ittnovi teoriji naj bi harmonični trizložni akordi ali triade v barvnem krogu tvorili enakostranične trikotnike, ki jih lahko poljubno rotiramo (slika 3). Najmočnejša triada je kombinacija primarnih barv rumene, rdeče in modre, sledijo triade sekundarnih oranžne, zelene in vijolične ter terciarnih rdečeoranžne, zelenorumene in modrovijolične.

Kot je razvidno iz grafov na slikah 17, 19, 21, tudi v CIE L*a*b*-barvnem prostoru te barve tvorijo trikotnike, vendar to niso enakostranični trikotniki, kot trdi Itten v svoji teoriji. Ravno tako kot pri dvozložnih barvnih akordih tudi pri trizložnih vsaka barva v a*, b*-diagramu leži v svojem kvadrantu. Kažejo se podobnosti z dvozložnimi akordi, saj so čiste barve najbolj oddaljene ena od druge, medtem ko se z zmanjševanjem čistosti in svetlosti barve približujejo koordinatnemu izhodišču in s tem ena drugi. Vrednosti a* in b* se z zmanjševanjem čistosti zmanjšujeta. To velja za vse tri trizložne akorde na slikah 17, 19 in 21.

CIE L*a*b*-sistem je sicer definiran kot sistem z enakimi prostorskimi razmiki, vendar geometrijski razmiki ne dajejo enakih zaznavnih razmikov. Zato izdelani trikotniki niso enakostranični, ker vizualne zaznave med barvami v CIE L*a*b*-sistemu niso enake. Podobno velja tudi v xy-diagramu, kjer so barve razporejene s pomočjo aditivnega mešanja barvnih svetlob in razmiki barv v dvodimenzionalnem diagramu niso vizualno enaki. Delno lahko krivimo tudi nepravilno izbrane barve in barve, ki jih je izbral Itten. Z malo drugačnimi barvami bi dobili za odtenek drugačne kote med barvami, vendar razlika ne bi bila bistvena. Pod nobenim pogojem v CIE-barvnem prostoru ne moremo dobiti enakostraničnih trikotnikov. Tudi v xy-diagramu trizložni akordi tvorijo trikotnike, vendar ne enakostraničnih. Opazno je tudi, da čiste primarne, sekundarne in terciarne barve zavzemajo največje trikotnike, vse druge barvne kombinacije so znotraj tega trikotnika, kar lahko vidimo na slikah 18, 20 in 22.

V CIE L*a*b*-sistemu in xy-barvnem diagramu lahko opazimo, da se pri primarnih barvah trikotniki najbolj manjšajo od čiste barve proti manj čisti, pri terciarnih barvah se velikost trikotnikov ne zmanjšuje, kar pomeni, da se čistost barv ne zmanjšuje, saj so te barve mešanice in tako že v osnovi niso tako čiste kot primarne barve rumena, rdeča in modra.

Posamezne barve imajo enake barvne tone h, enako kot je predstavljeno pri harmoničnih dvozložnih barvnih akordih. Če primerjamo barvne tone, ugotovimo, da rdeča in rumena med seboj tvorita kot 60°, rumena in modra 160° ter modra in rdeča 140°. V sekundarnih barvnih sestavih tvorita oranžna in zelena barva med seboj kot 70°, med zeleno in vijolično barvo je kot 160° in med vijolično in oranžno 130°. Pri terciarnih barvah so koti med posameznimi *of 160°, and purple and orange form an angle of 130°. Tertiary red-orange and green-yellow form an angle of 80°, green-yellow and blue-purple form an angle of 160°, and blue-purple and red-orange form an angle of 120°, as can be seen in Figure 15.*

4.4 Harmonic analogue colour chords

Analogue colour harmonies consist of three consecutive colour shades in the colour circle; we could also call them colour chords of relat-

barvami naslednji: med rdečeoranžno in zelenorumeno je kot 80°, med zelenorumeno in modrovijolično kot 160° ter med modrovijolično in rdečeoranžno kot 120°, kar lahko vidimo na sliki 15.

4.4 Harmonični analogni barvni akordi

Harmonične analogne barvne akorde sestavljajo trije v barvnem krogu zaporedni barvni odtenki, lahko bi rekli, da so barvni akordi sorodnih barv. Analogni barvni akordi rdeče barve so: rdeča, rdečevijolična in vijolična; svetlordeča, rdeča in rdečevijolična; oranžna, svetlordeča in rdeča. Barvni akordi rumene barve so: rumena, rumenooranžna in oranžna; rumenozelena, rumena in rumeno-

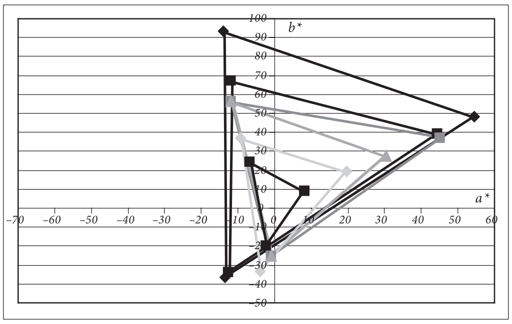


Figure 17: Primary colours in a, b* diagram.*

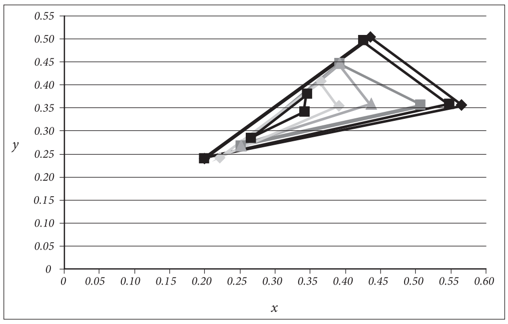


Figure 18: Primary colours in xy diagram.

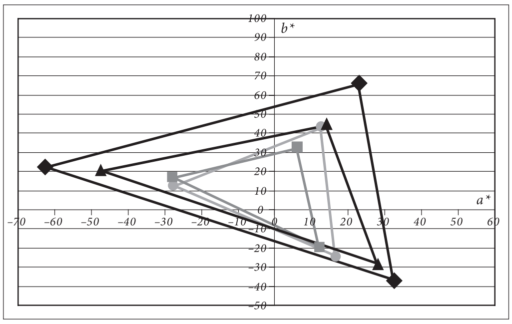


Figure 19: Secondary colours in a, b* diagram.*

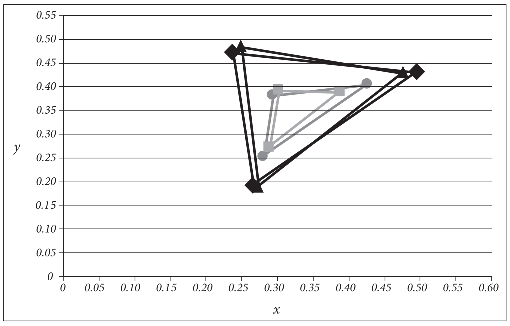


Figure 20: Secondary colours in xy diagram.

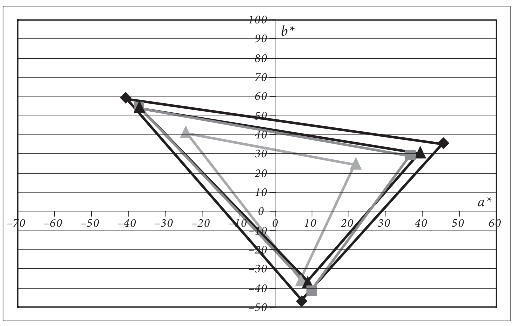


Figure 21: Tertiary colours in a, b* diagram.*

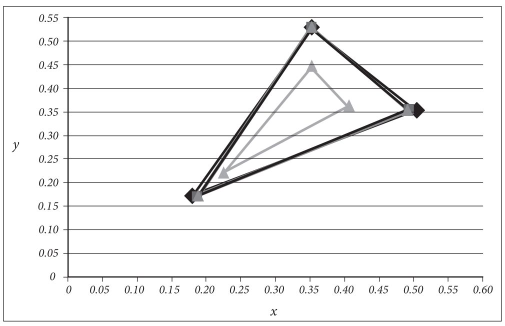


Figure 22: Tertiary colours in xy diagram.

ed colours. The analogue colour chords of red are: red, red-purple and purple; light red, red and red-purple; and orange, light red and red. The analogue colour chords of yellow are: yellow, yellow-orange and orange; yellow-green, yellow and yellow-orange; and green, yellow-green and yellow. The analogue colour chords of blue are: blue, light blue and blue-green; purple, blue and light blue; and red-purple, purple and blue.

Analogue colour chords also form triangles, but the triangles are smaller and positioned on the circumference of the colour circle, as shown on Figure 16.

The figure shows the organization of individual colour chords, their angles, and the intervals between them. As with all colour chords, only the colour shades (h) were analysed.

When comparing form analogue colour chords of yellow, we found that yellow and yellow-orange, as well as yellow-orange and orange, form an angle of 15°. The angle between yellow-green and yellow is 20°, the angle between green and green-yellow is 30°, and the angle between yellow-green and yellow is 25°.

The angles between form analogue colour chords of red are very wide. The reason is the same as with other analyses of colour shades (h) – the colours are widely spread around the colour circle. The defectiveness of Itten's colour theory is also shown in terms of the connection between red and purple. The angle between orange and light red is 25°, that between light red and red is 15°, that between red and red-purple is 80°, and that between red-purple and purple is 20°.

When analysing the angles between the analogue colour chords of blue, we have also seen that the angle between green-blue and light blue is quite wide (70°). The angle between blue and light blue is 20°, and that between purple and blue is 30°.

As shown on Figures 23, 24 and 25 we see that the triangles spread towards the inside of the xy diagram. That means that harmonies consist of colours of different lightness. All colours that form analogue harmonies are relatively close to the spectral line, while other colours spread in all directions.

oranžna; zelena, rumenozelena, rumena. Akordi modre barve so: modra, svetlomodra in modrozelena; vijolična, modra in svetlomodra; rdečevijolična, vijolična in modra.

Harmonični analogni barvni akordi med seboj prav tako tvorijo trikotnike, le da so ti manjši in razporejeni po obodu barvnega kroga, kar je razvidno iz slike 16. Prikazana je razporeditev posameznih barvnih akordov, vidi se, kakšne kote tvorijo med seboj in koliko so med seboj oddaljeni. Za primerjavo smo upoštevali le barvne tone h kot pri vseh prejšnjih barvnih akordih.

Pri primerjavi harmoničnih analognih barvnih akordov rumene barve smo ugotovili, da je kot med rumeno in rumenooranžno

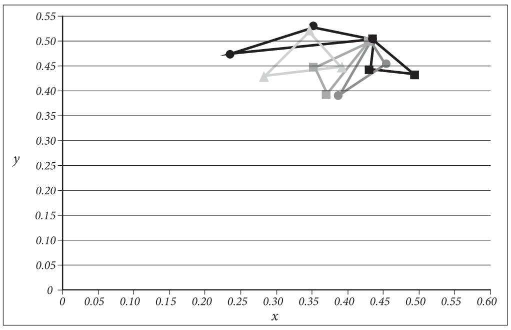


Figure 23: Yellow analogue colour chords.

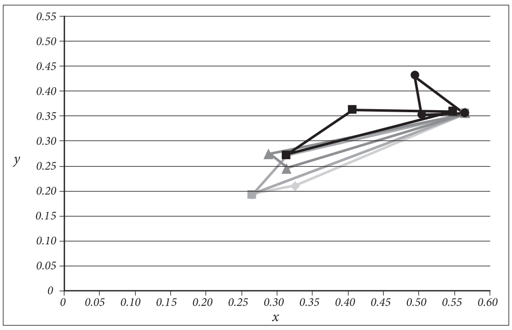


Figure 24: Red analogue colour chords.

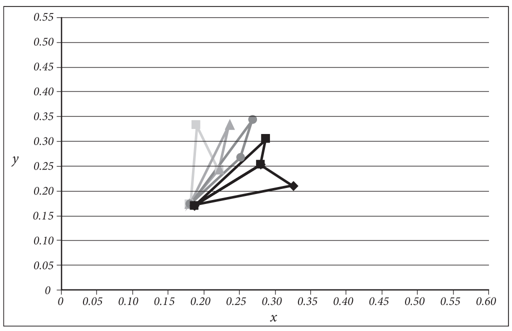


Figure 25: Blue analogue colour chords.

5 Conclusion

*J. Itten developed the theory of colour contrasts and harmonies, which is used in art. It is based on the visual perception of colours, which form a twelve-part colour circle. The aim of this research was to find out whether Itten's findings can be transferred into the CIE L*a*b and CIE xy colour system, and how the colours in these two systems are positioned.*

*According to Itten, yellow is the lightest and purple is the darkest colour. If we transfer the colours into the CIE L*a*b* colour space, we see that that is true – yellow has the highest and purple the lowest L*. The darkest colour is, of course, the black colour, which is not a part of the colour circle.*

If we look at the xy diagram of measured colours, we see that the colours do not spread over the whole diagram. Because the CMKY colour model covers only about a third of the white spectrum colours of the xy diagram, the colours are more or less on the inside. The green shows a great deficiency of colours towards the top of the horseshoe.

In both xy and a, b* diagrams, the colours progress in the same way as in the colour gamut. That shows that Itten's theory of the colour circle and monochromatic colour chords is correct, even if transferred into the CIE-colour space. The difference is only in the angles between adjoining colours.*

The complementary colour chords in the CIE-colour space lie in opposite quadrants, but the angle is not the same as in the colour circle (180°), where the complementary colours are diametrical. The colours in the xy diagram are also opposite to each other.

If we transfer the harmonic triads into the CIE-colour space, we get triangles of primary, secondary and tertiary colours, which are not equilateral as in the colour circle.

Both a, b* and xy diagram show that harmonies of pure colours form the biggest triangles. Inside them we find harmonies of less pure and saturated colours. In Itten's theory, the distances between colours are the same and result in equilateral triangles. In the CIE-colour space, the distances between colours are not visually the same and result in irregular triangles. The*

barvo ter med rumenooranžno in oranžno barvo 15°. Barvni kot med rumenozeleno in rumeno je 20°, med rumeno in rumenooranžno barvo 15°. Barvni kot med zeleno in rumenozeleno je 30°, med rumenozeleno in rumeno pa 25°.

V akordih rdeče barve so barvni koti med posameznimi barvami zelo veliki, kar lahko pripisujemo neenakomerni razvrščenosti barv po barvnem krogu, to pa se je pokazalo že pri primerjavi barvnih tonov (h) vseh izmerjenih barv. Tukaj se pokaže pomanjkljivost Ittnove teorije glede povezave med rdečo in vijolično barvo.

Tako je barvni kot med oranžno in svetlordečo 25°, med svetlordečo in rdečo 15°, kot med rdečo in rdečevijolično je 80°, kot med rdečevijolično in vijolično pa 20°.

Pri primerjavi barvnih akordov modre barve prihaja do dokaj velikih kotov med zelenomodro in svetlomodro barvo, kjer je barvni kot 70°, kot med modro in svetlomodro je 20°. Kot med vijolično in modro barvo je 30°.

Iz xy-barvnih diagramov (slike 23, 24, 25) lahko ugotovimo, da se trikotniki širijo proti notranjosti xy-diagrama, kar pomeni, da harmonije med seboj tvorijo barve različnih svetlosti. Vse barve, iz katerih izpeljujemo analogne harmonije, so sorazmerno blizu spektralne črte, medtem ko so druge barve razporejene v vse smeri.

5 Zaključki

V umetnosti se uporablja teorija barvnih kontrastov in harmonij, ki jo je postavil švicarski umetnik J. Itten. Temelji na vizualni zaznavi barv, ki so enakomerno razporejene v dvanajstdelni barvni krog. Z raziskovalnim delom smo hoteli ugotoviti, če barvne zakonitosti, ki jih je postavil Itten, lahko prenesemo v barvna sistema CIE L*a*b* in CIE xy in kako so barve v teh dveh sistemih razporejene.

Itten trdi, da je najsvetlejša barva rumena in najtemnejša vijolična, kar lahko potrdimo, tudi če barve prenesemo v CIE L*a*b*-barvni prostor, saj ima rumena barva največji L* (svetlost) v primerjavi z drugimi barvami in modrovijolična barva najmanjšega. Seveda je najtemnejša nepestra črna barva, ki ni vključena v barvni krog.

Če pogledamo xy-diagram izmerjenih barv, ugotovimo, da barve, ki smo jih uporabili, ne zavzemajo celotnega diagrama. Barve so v notranjosti xy-diagrama, saj CMYK-barvni model obsega le približno tretjino barv iz spektra bele barve, ki predstavlja xy-diagram. Velik primanjkljaj barv je viden v zgornjem delu podkve, kjer so zeleni barvni toni.

Barve si tako v xy- kot tudi v a*, b*-diagramu sledijo v enakem vrstnem redu kot barve v barvni lestvici, kar pomeni, da Ittnova teorija barvnega kroga in teorija o monokromatičnih barvnih akordih držita tudi v CIE-barvnem prostoru, razlika je le v različnih kotih med posameznimi barvami.

Komplementarni barvni akordi v CIE-barvnem prostoru ležijo v nasprotnih ali sosednjih kvadrantih, vendar kot med njimi ni 180°

chosen colours can be partly blamed for this occurrence. With the choice of only slightly different colour shades, different angles between colours could be achieved. It is impossible, though, to get equilateral triangles in CIE-colour space.
Analogue colour chords consist of three consecutive colour shades in the colour circle. They also form triangles, but they are smaller and positioned on the circumference of the colour circle. The positioning of colour harmonies in the xy diagram shows that the basic colours are closer to the spectral line, while the triangles spread towards the inside of the colour space.
Contiguous colours do not form the same angles. In some cases (for instance between red and red-purple), the angles are very wide. The positioning of colours depends on the basic positioning of colours in the colour circle.
In the analysis of all colour harmonies, the most important factor is hue. Regardless of lightness or chroma, the chosen colours share the same hue.

tako kot v barvnem krogu, kjer komplementarne barve ležijo diametralno. Podobno je v xy-diagramu, kjer si barve ravno tako ležijo nasproti.
Če harmonične trizložne barvne akorde prenesemo v CIE-barvni prostor, dobimo trikotnike, ki niso enakostranični, tako kot so v barvnem krogu.
Tako v a*, b*-diagramu kot tudi v xy-diagramu je opazno, da harmonije čistih barv tvorijo največje trikotnike, harmonije manj čistih in manj nasičenih barv pa ležijo znotraj večjih trikotnikov. V Ittnovi teoriji je trikotnik enakostraničen, ker so razmiki med barvami enaki. V CIE-barvnem prostoru razmiki med barvami niso vizualno enako razporejeni in zato prihaja tudi do nepravilnih trikotnikov. Del krivde lahko pripišemo tudi izbranim barvam, saj bi z izbiro malce drugačnih barvnih odtenkov dobili drugačne kote med barvami, vendar je enakostranične trikotnike v CIE- barvnem prostoru nemogoče dobiti.
Analogne harmonije sestavljajo trije v barvnem krogu zaporedni barvni odtenki, ki po obodu barvnega kroga prav tako tvorijo trikotnike, le da so ti manjši. Razporeditev barvnih harmonij v xy-diagramu pokaže, da so osnovne barve, iz katerih harmonije izhajajo, postavljene bolj proti spektralni črti, trikotniki pa segajo proti notranjosti barvnega prostora.
Sosednje barve med seboj ne tvorijo enakih barvnih kotov. Med posameznimi barvami, na primer med rdečo in rdečevijolično, so razlike v barvnem kotu zelo velike. Razporeditev barv je odvisna od osnovne razporeditve barv po barvnem krogu.
Za ugotavljanje vseh barvnih harmonij je najpomembnejši barvni ton, ne svetlost ali kroma barv, saj imajo izbrane barve v harmonijah ne glede na različno svetlost ali čistost enak barvni ton.

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