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Primerjava instrumentov za merjenje fasadnih barv z uporabo treh enačb za določanje barvnih razlik

Izvirni znanstveni članek

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Comparison of Instruments for Measuring Facade Colors Using Three Color Difference Equations

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Abstract

Applicability of three color difference equations, such as CIELAB, CIE94 and CIEDE2000, for facade surfaces was investigated. Facade samples have structured surface similar to textile fabric. Measurements were made with two spectrophotometers with different measurement geometries, Spectraflash SF600 (Datacolor) and Eye – One (X – Rite). For evaluation of matching of the facade sample with the template in color chart, visual assessment based on the gray scale was also used. From the results of the research it is evident that the most suitable equation for calculating color differences of facade surfaces is the CIEDE2000, while the least appropriate proved to be the CIELAB equation. It was also determined that the spectrophotometer Spectraflash SF600 (Datacolor) is more suitable for comparing colors of rough facade surfaces with the templates in the color scale and that the visual assessment based on the gray scale is pretty reliable.

Keywords: color measurement, color difference, facade surface, spectrophotometer, gray scale visual assessment.

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Izvleček

V raziskavi je preučevana uporabnost treh enačb za izračun barvnih razlik – CIELAB, CIE94 in CIEDE2000 – za fasadne površine, ki imajo strukturirano površino, podobno kot tekstilni izdelki. Meritve so bile izvedene z dvema spektrofotometroma z različnima merskima geometrijama, Spectraflash SF600 (Datacolor) in Eye-One (X-Rite). Ocena ujemanja fasadnega vzorca s predlogo v barvni karti je bila podana tudi na podlagi vizualne ocene s pomočjo devetstopenjske sive skale. Iz rezultatov raziskave je razvidno, da je najprimernejša enačba za izračun barvnih razlik na fasadnih površinah enačba CIEDE2000, najmanj primerna pa enačba CIELAB. Ugotovljeno je bilo, da je spektrofotometer Spectraflash SF600 (Datacolor) ustreznejši za primerjavo barve hrapavih fasadnih površin in predloge v barvnih kartah ter da je vizualno vrednotenje barvnih razlik na podlagi sive skale dokaj zanesljivo.

Ključne besede: merjenje barve, barvna razlika, fasadna površina, spektrofotometer, vizualna ocena po sivi skali.

1 Uvod

Barva je čutna zaznava, ki nastane v človeških možganih pod vplivom svetlobe. S tem, ko barve merimo, jih numerično ovrednotimo in omogočimo objektivno identifikacijo posamezne barve ter tako tudi kontrolo kakovosti obarvanih izdelkov [1, 2]. Za merjenje barv se uporabljajo kolorimetri ali spektrofotometri. Kolorimeter je sicer hiter in preprost za uporabo, vendar ima kar nekaj omejitev. Na voljo ima le eno vrsto osvetlitve, pogosto pa potrebu-

1 Introduction

Color is a sensual perception that occurs in a human brain under the influence of light. By measuring the color it is asigned numerical values and gets objective identification, which is useful for quality control of colored products [1, 2]. Color measurements are normally performed by means of colorimeters and spectrophotometers. Colorimeter enables fast and simple measurements but also has some limitations. It uses a single light source, while to obtain standardized tristimulus values and color differences; various light sources are often required. In comparison with colorimeter, spectrophotometer is a precise instrument that measures sample reflection in the whole visible spectrum and also enables calculation of tristimulus values under different light sources and therefore the assessment of metamerism [1].

For measuring colors on smooth surfaces, such as prints on paper or board, instruments with a plane geometry of illumination and observation (45/0) (Figure 1a) are recommended by standards, while for rough surfaces, such as textile and knitted fabric, instruments with a spherical geometry (D/0, D/8) are recommended (Figure 1b) [1, 3, 4, 5]. A problem arises when we want to compare colors of two materials with different surface structures. In our research, colors of structured facade surfaces were compared to those of smooth templates in a color chart.

Final plaster is used to protect and design the facade [6]. Three typical final plasters are silicate, silicon and acrylate plaster. All of them are paste–like and suitable for scratched and groove structures. In a scratched structure the particle size can be 0.5, 1, 1.5, 2 or 3 mm, an exception is silicon plaster where particle size ranges from 1.5 to 3 mm. Final plaster color is usually chosen from the producers color chart. These plasters are water-repellent, weather-resistant, have high permeability for vapour and are easy to use.

Goal of our research was to determine which of the two measurement geometries in this case enables a better matching of the calculated color differences with the visual assessment of an av-

jemo standardizirane barvne vrednosti in barvne razlike pri različnih vrstah osvetlitve. V primerjavi s kolorimetrom je spektrofotometer natančen instrument, ki meri refleksijo vzorca po celotnem vidnem spektru in omogoča izračun standardiziranih barvnih vrednosti pod različnimi pogoji osvetlitve ter s tem zaznavo metamerizma [1].

Za merjenje barve na gladkih površinah, kot so na primer odtisi na papirju in kartonu, standardi predvidevajo uporabo instrumentov z ravninsko geometrijo osvetlitve in opazovanja (45/0) (slika 1a), za merjenje barve hrapavih površin, kot so tkanine in pletenine, pa sferično geometrijo (D/8, D/0) (slika 1b) [1, 3, 4, 5]. Težava nastane, kadar želimo primerjati barvi na dveh materialih z različnima površinskima strukturama. V naši raziskavi smo primerjali barve na razgibani strukturi fasadnih površin z gladkimi predlogami v barvnih kartah.

Zaključni omet ščiti in oblikuje fasado [6]. Poznamo tri značilne zaključne omete; to so silikatni, silikonski in akrilni omet. Vsi so pastozni in primerni za praskano ter žlebičasto strukturo. Pri praskani strukturi je velikost zrn 0,5, 1, 1,5, 2 ali 3 mm, izjema je silikonski omet, pri katerem je velikost zrn od 1,5 do 3 mm. Barvo zaključnega ometa izberemo iz barvne karte proizvajalca. Značilnosti teh ometov so vodoodbojnost, vremenska odpornost, dobra prepustnost za paro in preprosta uporaba.

V raziskavi smo želeli ugotoviti, katera merska geometrija v takem primeru omogoča boljše ujemanje izračunanih barvnih razlik z vizualno oceno povprečnega opazovalca. V raziskavo smo zato vključili obarvane hrapave fasadne površine in njihove predloge v barvnih kartah, ki so bile natisnjene na gladkem premazanem papirju. Poleg tega smo želeli ugotoviti, katera od novejših enačb za numerično določanje barvnih razlik daje najboljše ujemanje z vizualnim zaznavanjem barvnih razlik. Barvne razlike smo izračunali z uporabo treh enačb (1–3) [2]:

1. enačba CIELAB za izračun barvnih razlik:

$$\Delta E^*_{ab} = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}} \tag{1}$$

2. enačba CIE94 za barvne razlike:

$$\Delta E^*_{94} = \left[\left(\frac{\Delta L^*}{k_L S_L}\right)^2 + \left(\frac{\Delta C^*_{ab}}{k_C S_C}\right)^2 + \left(\frac{\Delta H^*_{ab}}{k_H S_H}\right)^2\right]^{\frac{1}{2}} \tag{2}$$

3. enačba CIEDE2000 za barvne razlike [2, 7]:

$$\Delta E_{00} = \left[\left(\frac{\Delta L'}{k_L S_L}\right)^2 + \left(\frac{\Delta C'}{k_C S_C}\right)^2 + \left(\frac{\Delta H'}{k_H S_H}\right)^2 + R_T\left(\frac{\Delta C'}{k_C S_C}\right)\left(\frac{\Delta H'}{k_H S_H}\right)\right]^{\frac{1}{2}} \tag{3}$$

erage observer. Consequently, both rough colored facade surfaces and their templates printed on a smooth coated paper were applied. Besides, we also wanted to find out which of the three equations for numerical evaluation of color differences offers the best correlation with the visual perception of color shifts. Three equations (1–3) for the calculation of color differences are [2]:

1. *CIELAB equation (1),*
2. *CIE94 equation (2)*
3. *CIEDE2000 equation [2, 7] (3)*

2 Experimental

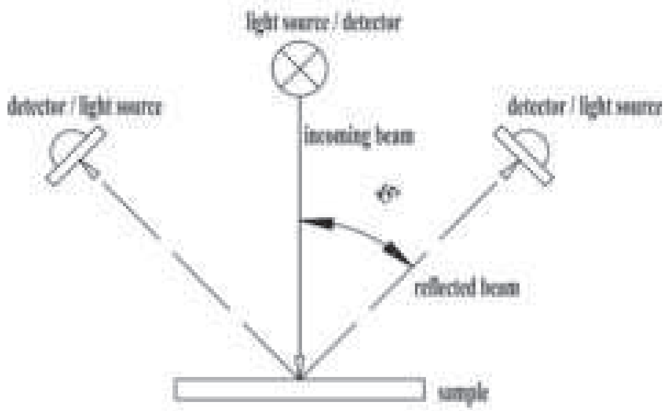
2.1 Selection of samples

22 facade color samples (size 5 × 8.5 cm) and their 22 templates in the color chart (as standard) were used for measuring (Figure 2). Colors in the chart were represented on a smooth surface, while colored facade samples had a rough or non–uniform surface with 1.5 mm large grains. Our purpose was to include as large number of colors in the visible spectrum as possible, so the samples were sellected according to their color hue (tone). In addition, two samples of each color hue with different saturation levels (most and least saturated) were selected.

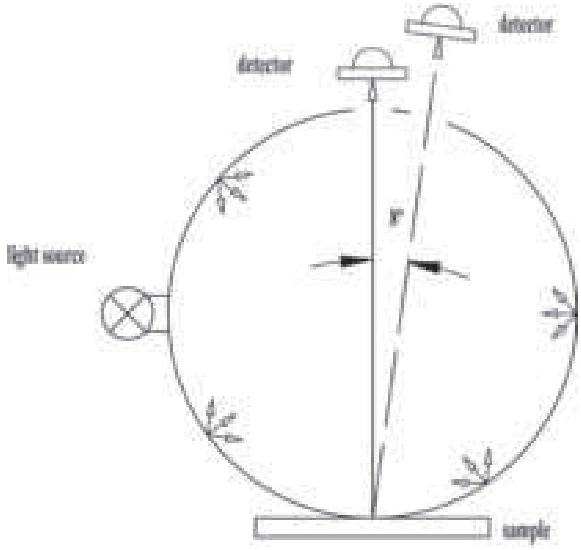
2.2 Measurements

Due to their different characteristics, measurements with two spectrophotometers, Eye – One (X – Rite) (designated as i1) and Spectraflash SF600 (Datacolor) (designated as SF600), were performed. SF600 that uses CIE 1964 Standard Colorimetric Observer (10°) is more appropriate for measuring colors on larger surfaces than spectrophotometer i1 where results are obtained using the CIE 1931 Standard Colorimetric Observer (2°). Spectral response of colors was measured in the range from 380 to 730 nm (with i1) and from 360 to 700 nm (with SF600). Based on these data, values X, Y, Z, L, a*, b*, C^*_{ab} and h_{ab} were then calculated.*

10 measurements on each sample and 3 measurements on each standard with i1 and 7 measurements on each sample and 3 measurements on each standard with SF600 were carried out. Characteristics of both spectrophotometers are displayed in Table 1.



a) plane geometry



b) spherical geometry

Figure 1: Measuring geometry: a) plane geometry (45/0, 0/45), b) spherical geometry (D/0, 0/D, D/8 and 8/D). (Author: Jernej Dovjak)

2 Eksperimentalni del

2.1 Izbira vzorcev

Za izvedbo meritev smo uporabili 22 vzorcev fasadnih barv in 22 vzorčnih predlog v barvni karti (slika 2). Velikost vzorcev je bila 5 × 8,5 cm, standard pa je bila barvna karta. Posamezne barve v barvni karti so bile predstavljene na gladki podlagi, medtem ko so bili vzorci hrapavi oziroma so imeli neravno podlago, njihova zrnatost je bila 1,5 mm. Vzorce smo izbirali glede na barvni ton, saj smo želeli zajeti čim več barv v vidnem delu spektra. Pri posameznem barvnem tonu pa smo izbrali še vzorca, ki sta se razlikovala po nasičenosti.

2.3 Visual assessment of color differences

For the visual evaluation, a nine-step gray scale was used [8]. Facade sample and standard were compared with the gray scale in a neutral gray surrounding in a light chamber (Gretag Macbeth) using a day light (D65) illumination. Samples were viewed at an angle of 45° with respect to the light source. Matching of color samples was assessed by 14 women and 10 men. Visual assessment was given as the mean value based on 3x evaluation of each sample and its template.

2.4 Use of Plug-in Color Inspector 3D (v2.3)

With color analysis using an image processing program ImageJ [9] and its plug-in Color Inspector 3D (v2.3) [10] we wanted to confirm the results obtained by visual evaluation. Color charts templates and facade colors were acquired with Epson Perfection 4990 Pro scanner. Parameters for both image acquisition – scanning – and creating the scanner profile using i1reference target and programme i1Match were the same: resolution: 600 dpi, gamma: 3, bit depth: 48 bit HDR. Images were saved as 16-bit RGB tiff files. Since the plug-in requires smaller images, these were converted into 8-bit images. Each one was assigned the corresponding scanner profile. Since Color Inspector 3D requires images in sRGB color space, the scanner profile was converted into standard profile sRGB IE61966–2.1 with absolute colorimetric rendering intent where lightness axis is settled near D50. Afterwards, pictures were analyzed with the above mentioned plug-in.

3 Results and discussion

Results show that the smallest mean color differences are obtained when applying ΔE_{00} *equation. This was expected since this formula includes the largest number of correction parameters, such as lightness-, chroma- and hue correction terms as well as correction of ellipses orientation in blue area. Values of obtained color differences calculated with* ΔE^*_{94} *are in most of the cases higher than when applying* ΔE_{00} *formula and lower than when applying* ΔE^*_{ab}.

Figure 2: Color samples.

2.2 Meritve

Za merjenje vzorcev smo uporabili dva spektrofotometra: Eye-One (X-Rite), v nadaljevanju i1, in Spectraflash SF600 (Datacolor), v nadaljevanju SF600, in sicer zaradi njunih različnih karakteristik. Ker SF600 upošteva standardnega barvnometričnega opazovalca CIE 1964 (10°), je primernejši za merjenje barve na večjih površinah kot spektrofotometer i1, ki podaja rezultate na osnovi standardnega barvnometričnega opazovalca CIE 1931 (2°). S spektrofotometrom smo merili spektralni odziv barv v območju od 380 nm do 730 nm (i1) in od 360 do 700 nm (SF600), iz teh podatkov pa so bile izračunane vrednosti X, Y, Z, L^*, a^*, b^*, C^*_{ab} in h_{ab}.

Table 1: Characteristics of Eye – One (X – Rite) and Spectraflash SF600 (Datacolor) spectrophotometers.

Type	Eye – One	Spectraflash SF600
Light source	D50	D65
Standard observer	2°	10°
Measurement geometry	45/0	D/8
Spectral range (nm)	380–730	360–700
Aperture (mm)	4	MAV (2r = 20)
No. of layers	1	1
No. of measurements on each sample	10	7
Calibration standard	white	white and black
Measuring steps (nm)	10	5

From the measurements it was clear that higher color differences appeared in case of brighter samples. This is due to the fact that the human eye is more sensitive to changes in brighter shades of color than to darker ones. Calculations also lead to the conclusion that lower color differences were obtained when using spectrophotometer SF600. SF600 is therefore more appropriate for color measurements on facade surfaces than spectrophotometer i1; note that color differences obtained by visual evaluation were low.

When using spectrophotometer SF600, equations ΔE^*_{ab} and ΔE^*_{94} produce similar results, with the exception of more saturated yellow, ochre and red samples. In case of smaller color differences ($\Delta E < 3$) all three equations are comparable (this is true also for the sample 3271 where $\Delta E^*_{ab} = 4.6$) while for other samples ΔE_{00} values are generally lower (Figure 3).

When using i1 and in case of smaller color differences ($\Delta E < 3$), all three equations are comparable. Results obtained with equations ΔE^*_{ab} and ΔE^*_{94} are similar except for more saturated yellow and ochre samples, probably because these two colors have higher lightness and saturation. Almost all obtained ΔE_{00} values are smaller; exceptions are samples 3271 and 3301, where ΔE_{00} value is slightly higher than the ΔE^*_{94} value (Figure 4).

Color differences based on SF600 measurements are – for all three color difference equations – virtually always smaller than those obtained with i1; exception is the gray sample 3271. Smaller color difference is also evident from the mean color difference values (Table 2). We can therefore conclude that instrument SF600 is more suitable for measuring color differences on rough facade surfaces.

According to the obtained results we can conclude that the calculated color differences exhibit a good matching with visual assessment based on gray scale. Figure 5 shows mean visual evaluation scores of 14 women and 10 men together with the calculated color differences based on measurements with SF600. Lowest average color difference was 3.3, while highest one was 4.7. Samples 3011 (more saturated) and 3271 (more saturated) received lowest average evaluation score, while samples 3125 (less

S spektrofotometrom i1 smo izvedli 10 meritev na posameznem vzorcu in 3 meritve na posameznem standardu, s spektrofotometrom SF600 pa 7 meritev na posameznem vzorcu in 3 meritve na posameznem standardu. V preglednici 1 so podane karakteristike obeh uporabljenih spektrofotometrov.

2.3 Vizualno vrednotenje barvnih razlik

Za vizualno oceno smo uporabili devetstopenjsko sivo skalo [8]. Vzorec in standard smo primerjali s sivo skalo v nevtralno sivi okolici v osvetljevalni komori (Gretag Macbeth) pod dnevno svetlobo (D65). Vzorci so bili postavljeni pod kotom 45° glede na svetlobni vir. Ujemanje vzorcev je ocenjevalo 14 žensk in 10 moških. Vizualno oceno smo podali kot povprečno vrednost na podlagi trikratnega ocenjevanja posameznega vzorca in njemu pripadajočega standarda.

2.4 Uporaba vtičnika (plug-ina) Color Inspector 3D (v2.3)

Z analizo barve vzorcev s pomočjo programa za slikovno procesiranje ImageJ [9] in njegovega vtičnika Color Inspector 3D (v2.3) [10] smo želeli podkrepiti ugotovitve, dobljene z vizualno oceno. Predloge v barvni karti in pobarvane fasade smo zajeli z optičnim čitalcem Epson Perfection 4990 Pro. Pri zajemanju smo uporabili vedno enake pogoje, tako kot pri izdelavi profila optičnega čitalca s pomočjo referenčne tablice i1 v programu i1 Match. Pogoji zajemanja slik in izdelave profila so bili: ločljivost: 600 dpi, gama: 3, bitna globina: 48 bit HDR. Slike smo shranjevali kot .tiff in dobili 16 bit RGB. Za delo z vtičnikom potrebujemo manjše slike, zato smo jih spremenili v 8 bit. Pripeli smo jim ustrezen profil optičnega čitalca. Color Inspector 3D zahteva slike v barvnem prostoru sRGB, zato je bilo treba narediti pretvorbo iz profila optičnega čitalca v standardni profil sRGB IE61966-2.1 s pomočjo absolutno kolorimetričnega upodobitvenega načina, ki gradi svetlostno os okrog D50. Nato smo slike analizirali z omenjenim vtičnikom.

3 Rezultati z razpravo

Rezultati so pokazali, da najnižje vrednosti povprečnih barvnih razlik dobimo pri izračunih po enačbi ΔE_{00}. To je bilo v skladu s pričakovanji, saj ima ta formula največ korekcijskih faktorjev, kot so korekcija razlike v svetlosti, razlike v kromi, razlike v barvnem tonu in korekcija orientacije elips v modrem področju. Vrednosti, dobljene po enačbi ΔE^*_{94}, so bile v večini primerov višje od vrednosti, izračunanih po enačbi ΔE_{00}, in nižje od vrednosti, izračunanih po enačbi ΔE^*_{ab}.

Na podlagi meritev smo ugotovili, da dobimo pri svetlejših vzorcih višje barvne razlike kot pri temnejših vzorcih, kar izhaja iz dejstva, da je človeško oko občutljivejše za spremembe v svetlih tonih. Na podlagi izračunov pa smo ugotovili, da pri večini vzorcev dobimo nižje vrednosti barvnih razlik, če so bile njihove vredno-

saturated) in 3301 (more saturated) received the highest one. The highest color differences were calculated with all three equations for the sample 3011 (more saturated) and the smallest ones for the samples 3121 (more saturated) and 3301 (more saturated). Using the spectrophotometer i1 the result was similar only in the case of sample 3011.

Assessment of color differences based on measurements with a spectrophotometer is more objective than a visual assessment based on gray scale, because results are more accurate, however,

sti izmerjene s spektrofotometrom SF600, iz česar sledi, da je ta spektrofotometer primernejši za merjenje fasadnih površin kot spektrofotometer i1, saj so bile barvne razlike, ocenjene vizualno, zelo majhne.

Pri merjenju s spektrofotometrom SF600 enačbi ΔE^*_{ab} in ΔE^*_{94} dajeta dokaj primerljive rezultate, razen pri bolj nasičenih vzorcih rumene, oker in rdeče. Pri manjših barvnih razlikah ($\Delta E < 3$) so vse tri enačbe dokaj primerljive, tudi pri vzorcu 3271, ki ima ΔE^*_{ab} = 4,6, pri drugih vzorcih pa je ΔE_{00} manjša (slika 3).

V primeru uporabe instrumenta i1 vse tri enačbe dajo podobne rezultate pri majhnih barvnih razlikah ($\Delta E < 3$). Enačbi ΔE^*_{ab} in ΔE^*_{94} dajeta podobne rezultate, razen v primeru bolj nasičene rumene

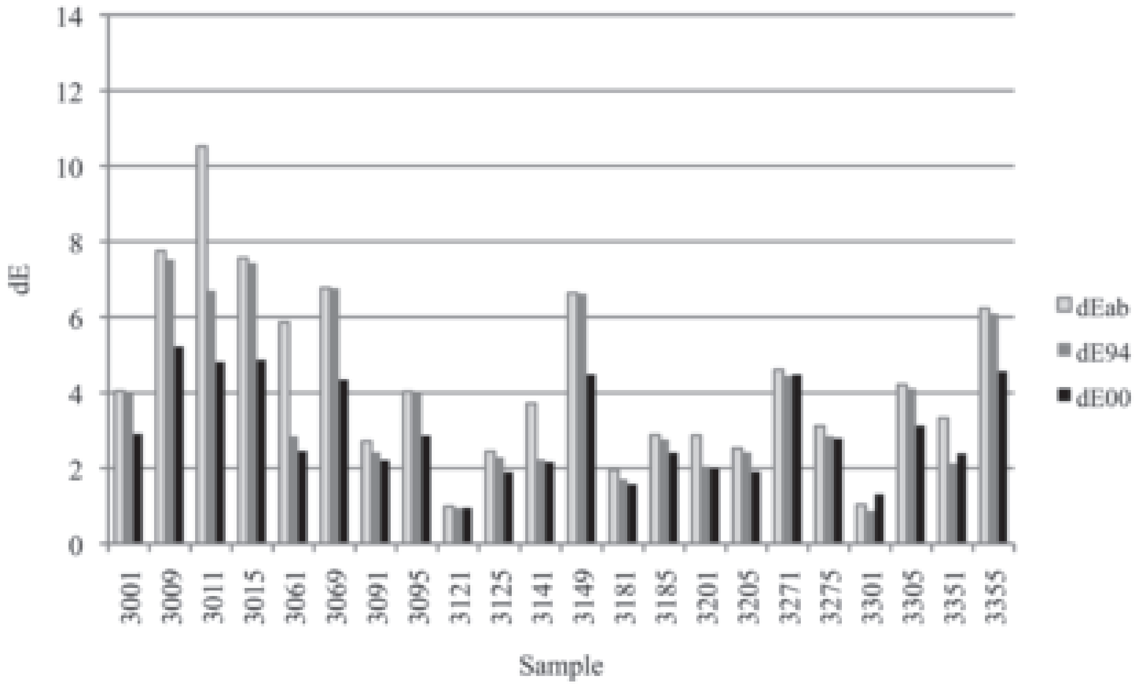


Figure 3: Color differences obtained with spectrophotometer Spectraflash SF600 (Datacolor); dEab-ΔE^*_{ab}, dE94-ΔE^*_{94} and dE00-ΔE_{00}.

visual assessment based on gray scale is cheaper and according to our results quite reliable.

By performing color analysis with the ImageJ plug-in Color Inspector 3D (v2.3) we we were trying to confirm the results obtained by visual evaluation. Results show that color represented in 3D space is in accordance with visual evaluation. Figures 6-8 show the sample with the lowest visual score (3011) is much higher on the lightness axis, while two other colors with the smallest color difference (3121 in 3301) are located in the middle of the lightness axis. This finding also supports the well-known fact that a human eye is more sensitive to bright color

in oker, kar je verjetno posledica višje svetlosti in večje nasičenosti teh dveh vzorcev. Pri ΔE_{00} skoraj v vseh primerih dobimo manjše barvne razlike, razen pri vzorcih 3271 in 3301, pri katerih je ΔE_{00} nekoliko večja od ΔE^*_{94} (slika 4).

Barvna razlika, izračunana po vseh treh enačbah, je pri merjenju s spektrofotometrom SF600 v vseh primerih manjša, izjema je le vzorec 3271 (siva). Manjša barvna razlika je razvidna tudi iz povprečnih vrednosti barvnih razlik (preglednica 2). Iz tega lahko sklepamo, da je instrument SF600 primernejši za določanje barvnih razlik pri hrapavih fasadnih barvah.

Izračunane barvne razlike se dobro ujemajo z vizualnimi ocenami po sivi skali. Na sliki 5 so poleg barvnih razlik, izračunanih na podlagi meritev z instrumentom SF600, prikazane povprečne ocene opazovalcev (14 žensk in 10 moških). Najnižja povprečna vizualna

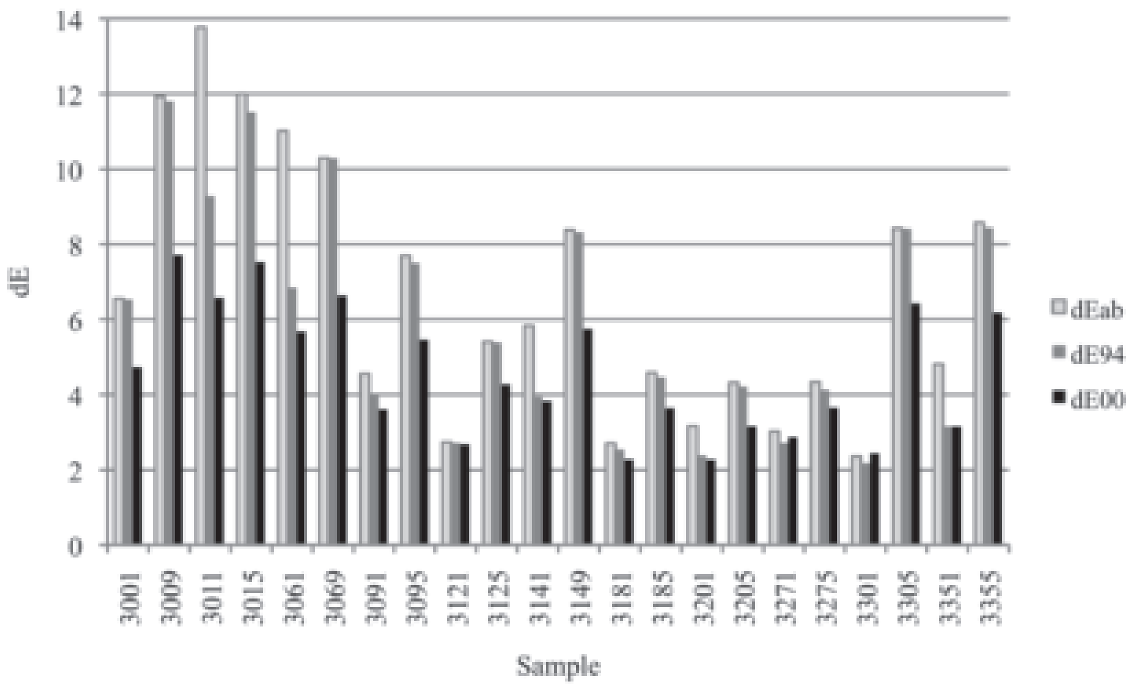


Figure 4: Color differences obtained with spectrophotometer Eye – One (X – Rite); dEab-ΔE^*_{ab}, dE94-ΔE^*_{94} and dE00-ΔE_{00}.

changes and that these are perceived more easily and faster.

4 Conclusion

Research results show that the most suitable equation for color difference calculation on facade surfaces and also for matching color of facade surface with template in color chart is CIEDE2000, while the least suitable equation is CIELAB. Spectrophotometer Spectraflash SF600 (Datacolor) proved better for purposes of comparison of color on rough facade surfaces and its templates in color charts. Assessment of color differences based on measurements with a spectrophotometer is more objective than a visual assessment based on gray scale, because results are more accurate, however, visual assessment is cheaper and according to our results quite reliable. For that reason we can conclude that the color of a facade can be chosen from a color chart. More accurate and objective results require the use of an appropriate spectrophotometer. Color analysis with ImageJ plugi-n Color Inspector 3D (v2.3) confirmed the results obtained by visual evaluation.

ocena je bila 3,3, najvišja pa 4,7. Vzorca 3011 (bolj nasičen) in 3271 (bolj nasičen) sta dobila najnižjo skupno oceno, vzorci 3121 (bolj nasičen), 3125 (manj nasičen) in 3301 (bolj nasičen) pa najvišjo. Za vzorec 3011 (bolj nasičen) je bila na osnovi vseh treh enačb izračunana največja barvna razlika, za vzorca 3121 (bolj nasičen) in 3301 (bolj nasičen) pa najmanjša. Meritve s spektrofotometrom i1 so pokazale podoben rezultat samo v primeru vzorca 3011.

Table 2: Mean color differences ΔE^*_{ab}, ΔE^*_{94} and ΔE_{00} calculated from measurements with spectrophotometers Eye – One (X – Rite) and Spectraflash SF600 (Datacolor).

Spectrophotometer	ΔE^*_{ab}	ΔE^*_{94}	ΔE_{00}
Eye-One	6.65	5.93	4.57
SF600	4.35	3.68	2.99

Vrednotenje barvnih razlik na podlagi meritev s spektrofotometrom je objektivnejše od vrednotenja na podlagi sive skale, saj so rezultati natančnejši, vendar pa je vrednotenje na podlagi sive skale cenejše, in kot kažejo naše meritve, dokaj zanesljivo.
Z analizo barve vzorcev s pomočjo vtičnika Color Inspector 3D (v2.3) smo želeli podkrepiti ugotovitve, dobljene z vizualno oceno. Prikaz barve v 3D-prostoru je pokazal ujemanje z vizualno oceno. Na slikah 6–8 vidimo, da je vzorec, ki je slabše ocenjen (3011), po svetlosti zelo visoko na svetlostni osi, medtem ko sta drugi dve prikazani barvi z najmanjšo barvno razliko (3121 in 3301) na sre-

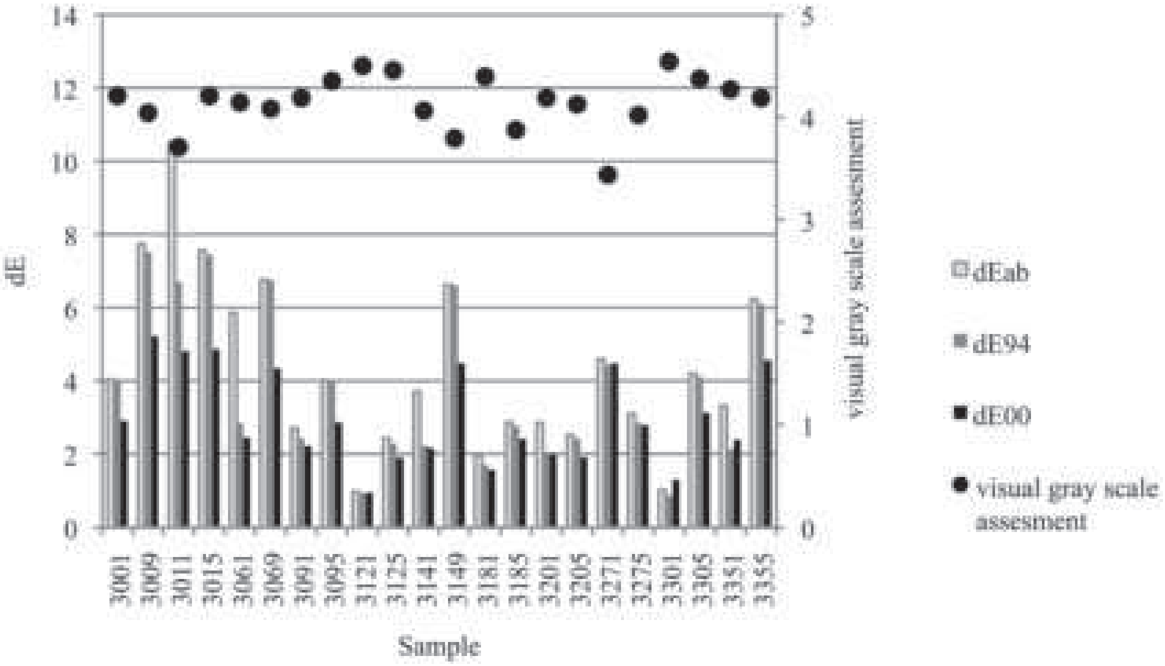


Figure 5: Matching of visual observation with color differences calculated with three equations. Measurements were performed with spectrophotometer Spectraflash SF600 (Datacolor); dEab-ΔE^*_{ab}, dE94-ΔE^*_{94} and dE00-ΔE_{00}.

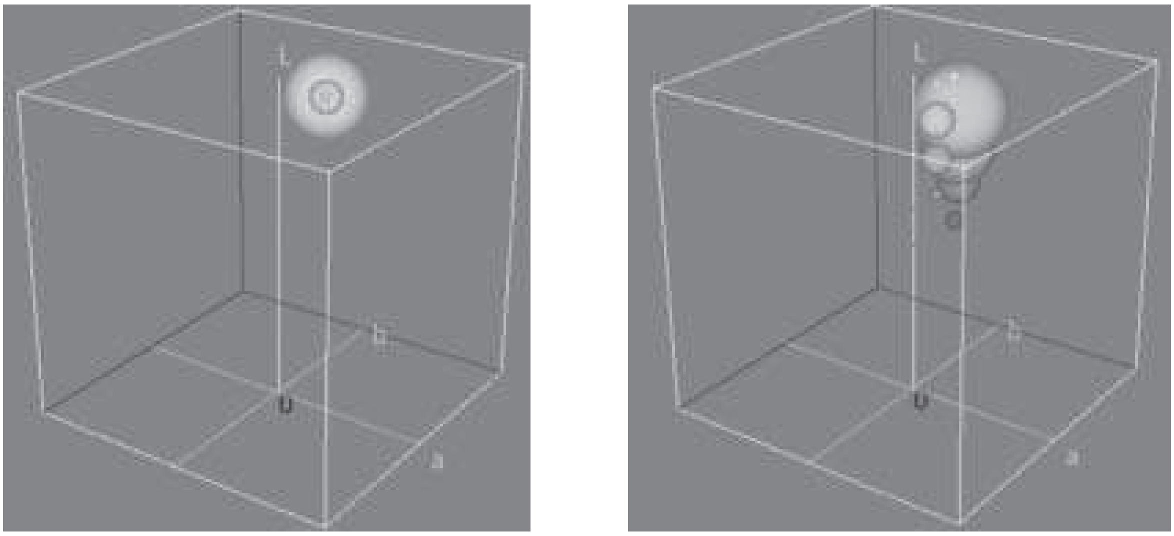


Figure 6: The color (3011) displayed in 3D color space: a) color chart, b) facade surface.

dini svetlostne osi. To je tudi dokaz, da je oko občutljivejše za spremembe v svetlih barvah in da le-te lažje oziroma hitreje zazna.

4 Zaključek

Iz rezultatov raziskave je razvidno, da je najprimernejša enačba za izračun barvnih razlik na fasadnih površinah ter za primerja-

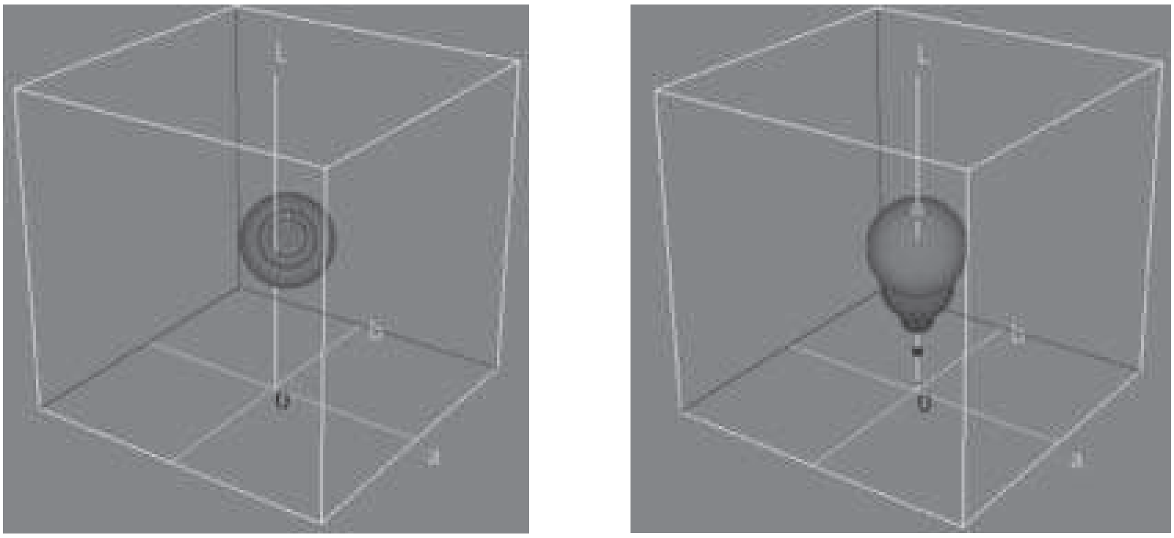


Figure 7: The color (3121) displayed in 3D color space: a) color chart, b) facade surface.

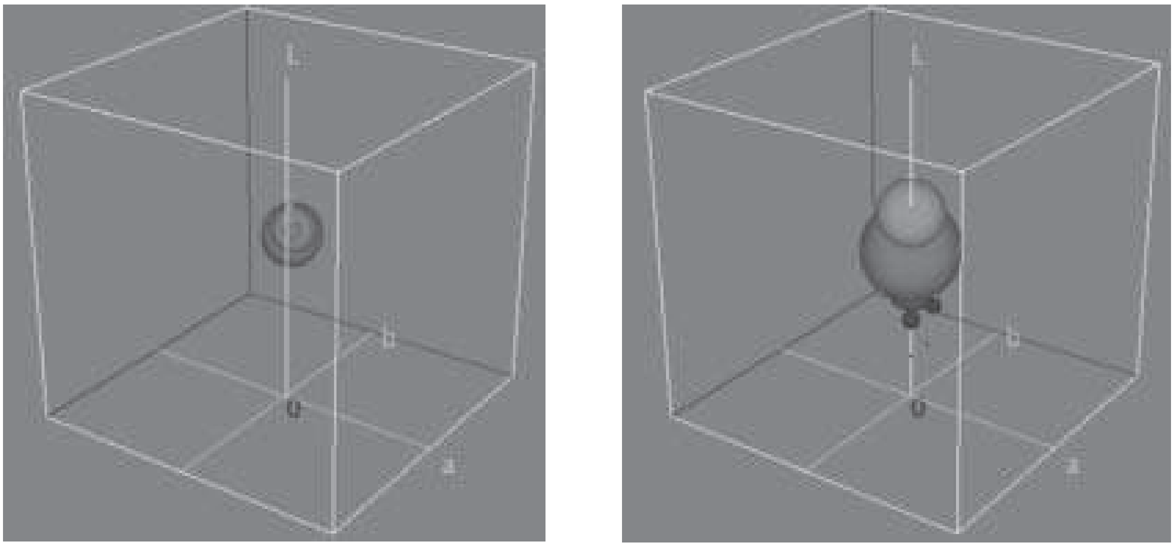


Figure 8: The color (3301) displayed in 3D color space: a) color chart, b) facade surface.

vo barve fasadnih površin in predloge v barvni karti enačba CIEDE2000, najmanj primerna pa enačba CIELAB. Ugotovljeno je bilo, da je spektrofotometer Spectraflash SF600 (Datacolor) ustreznejši za primerjavo barve hrapavih fasadnih površin in predloge v barvnih kartah. Vrednotenje barvnih razlik na podlagi meritev s spektrofotometrom je objektivnejše od vrednotenja na podlagi sive skale, saj so rezultati natančnejši, vendar pa je vrednotenje na podlagi sive skale cenejše, in kot kažejo naši rezultati, dokaj zanesljivo. Iz tega lahko sklepamo, da je barvo fasade mogoče izbrati s pomočjo barvne karte. Za natančnejše in objektivnejše rezultate pa je potrebna uporaba ustreznega spektrofotometra. Z analizo barve vzorcev z vtičnikom Color Inspector 3D (v2.3) smo potrdili ugotovitve, dobljene z vizualno oceno.

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