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Postupak ocjene doktorskog rada

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NASLOV RADA na hrv. jeziku:	Metoda za definiranje odnosa između kvantitativnoga pokazatelja i ljudske percepcije odstupanja u boji
NASLOV RADA na engl. jeziku:	Method for defining the relationship between a quantitative indicator and human perception of color deviation

SAŽETAK:

Percepcija boje kod humanog promatrača predstavlja subjektivni doživljaj, što otežava njenu kvantifikaciju i određivanje prihvatljivih tolerancija za odstupanje boje od referentne vrijednosti u bilo kojoj industrijskoj proizvodnji. U disertaciji je prikazana originalna metoda zasnovana na originalnom računalnom programu ColorChanger koja na jednostavan način omogućava da se pojedini ispitanik testira u pogledu percepcije razlika u boji te da se kvantitativno okarakterizira pokazateljima kao što su prag osjetljivosti, jedva primjetna razlika i neprihvatljiva razlika. Testiranje se provodi na proizvoljno definiranom skupu boja, uz poštivanje uvjeta da se zadana boja može prikazati na korištenom kalibriranom zaslonu. Ispitaniku se na kalibriranom zaslonu prikazuje referentno i promjenjivo polje boje, a ispitanik reagira kada primijeti da se polja razlikuju i kada razlika postane neprihvatljivo velika. Na temelju odgovora ispitanika računalni program ColorChanger bilježi L*a*b* koordinate promjenjivog polja na koje ispitanik reagira te se kvantitativno izražava odstupanje u boji pomoću odabrane jednadžbe za izračun ΔE. Uspoređeni su rezultati ispitivanja dviju grupa ispitanika razvrstanih po spolu, od kojih je bilo 10 ženskih i 10 muških, za određeni skup od 24 boje. Utvrđeni su određeni trendovi koji se mogu pripisati pripadnosti određenoj spolnoj grupi. Sprovedeno je ocjenjivanje i rangiranje ispitanika u pogledu osjetljivosti za razlike u boji za pojedine boje i više odabranih boja. Pokazano je da se može odrediti prosječna vrijednost praga osjetljivosti, jedva primjetne razlike i neprihvatljive razlike ispitivane grupe za kompletan skup boja obuhvaćenih testiranjem. Prag osjetljivosti za 75 % ispitanika iz grupe iznosi $\Delta E \leq 1{,}09$. Jedva primjetna razlika za 75 % ispitanika iznosi $\Delta E \leq 3{,}04$. Neprihvatljiva razlika za 75 % ispitanika iznosi $\Delta E \leq 5{,}82$. U disertaciji je dokazano je da se rezultati testiranja ispitanika mogu primijeniti na situacije kada ispitanik promatra boje dobivene suptraktivnom sintezom u procesu tiskanja. Metodom opisanom u ovom radu može se kvantificirati ΔE za bilo koju procesnu ili spotnu boju koja se može reproducirati u gamutu zaslona na kojem se provodi testiranje.

Ključne riječi:

Percepcija boje, odstupanje u boji, osjetljivost promatrača, tolerancija.

ABSTRACT:

Perception of a color by a human observer is a subjective experience, making it difficult to quantify and determine acceptable tolerances for deviation of color from a reference value in any industrial production. This dissertation presents an original method based on the original computer program ColorChanger, which easily allows an individual subject to be tested for the perception of color differences and to be quantitatively characterized by indicators such as sensitivity threshold, barely noticeable difference and unacceptable difference. Testing is performed on an arbitrarily defined set of colors where the default color can be displayed on a calibrated screen. The subject is shown a reference and variable color field on a calibrated monitor, and the subject responds when he notices that the fields are different and when the difference becomes unacceptably large. Based on the subject's response, the computer program ColorChanger records the L * a * b * coordinates of the variable field to which the subject responds and quantifies the color deviation using a selected equation to calculate ΔE. It is determined that the test results of the subjects can be applied to situations when the subject observes the colors obtained by subtractive synthesis in the printing process. Using the method described in this paper, it is possible to quantify ΔE for any spot color that can be reproduced in the gamut of the screen on which the test is performed. Respondents can be assessed and ranked in terms of sensitivity to color differences of individual colors or multiple selected colors according to any criteria (according to tone, brightness, contrast, position in the selected color space, color atlas, color chart, etc.)...

Methodology

The system consists of a computer, an expanded gamut calibration monitor, a spectrophotometer with calibration software and originally developed software to carry out the test method. Software has the following functions:

- It allows the researcher to generate an initial set of reference colored fields, that will be shown to the subject during the experiment.
- It allows the researcher to adjust the conditions of the experiment (the size, spacing and background color of the reference and variable fields, the step of changing colors, the extent to which colors change, the speed at which colors change, the number of changes per second, to show fields randomly ...).
- It allows the researcher to define a data set for the respondent, which can include personal data of respondent, which can be important for future research. The first three functions are accomplished by creating a configuration file.
- It automatically registers the L * a * b * values when the respondent reacts to the variable color field.
- It automatically calculates color difference ΔE according to the selected equation (in this work the $\Delta E\ ^*_{00}$ was selected).
- At the end of the test the software automatically generates a table with L*a*b* and $\Delta E\ ^*_{00}$ values of all fields, recorded when the respondent adjusts color of changeable field to be equal as reference field or confirmes the slightest noticeable or unacceptable color difference between reference and changeable fields.

The procedure consists of two series of tests. In each series the two fields of known colorimetric values – the reference field and adjustable or changeable field are shown to respondent whose task is to react to color changes. The first test determines the threshold of the respondent's sensitivity to particular reference color. In the second test the respondent decides upon the slightest (barely visible) and the unacceptable difference in the coloring of the two fields. The software collects the data from the test and generates a table of an individual respondent's sensitivity to color difference.

Main results

The device and method are convenient for quantification of an individual observer's tolerance to color difference for one or more specific color. Since initial setting can be adjusted, this method can be used to test the color perception of a certain human observer to a particular color or a set of colors. A typical example for this is when manufacturer of a colored product and his client are trying to objectively determine color tolerance that is acceptable for both parties.

This method enables a constant check on the person responsible for choosing and evaluating the color, the person who makes final decision of acceptance or rejection of the product, for instance in printing, packaging, coating, automotive, chemical and many other industries.

In many aforementioned studies, it is assumed that a human observer's perception of color difference changes over time and is subject to many influences. Those changes for one particular respondent can be easily tracked by his re-testing under the same circumstances and using the same ΔE formula for data processing.

This method offers tools to challenge the personalization of tolerance values to color difference sensitivity for each respondent. Of course, personalization will not directly influence color reproduction technologies, but it can cut some steps in it due to more strict tolerance values.

It has been shown that the average value of the sensitivity threshold, barely noticeable differences and unacceptable differences of the test group can be determined for the complete set of colors covered by the test. The sensitivity threshold for 75% of respondents in the group is $\Delta E_{00} \leq 1.09$. The barely noticeable difference for 75% of respondents is $\Delta E_{00} \leq 3.04$. An unacceptable difference for 75% of respondents is $\Delta E_{00} \leq 5.82$.

Certain trends have been identified that can be attributed to belonging to a particular gender group. The results have been obtained by testing two different gender groups: a group of ten male and a group of ten female subjects, who were asked to compare a specific set of 24 colour. Gender differences are not large, but there are still some statistically significant indicators that indicate the following:

- Women have a lower sensitivity threshold for 17% of colors, and men for 8% of colors.
- Women have a lower barely noticeable difference for 46% of colors.
- Women have a lower unacceptable difference for 13% of colors.

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