SVEUČILIŠTE U ZAGREBU
GRAFIČKI FAKULTET
ZAGREB, Getaldićeva 2

Postupak ocjene doktorskog rada

DOKTORAND/ICA:	Aleksanda Bernašek Petrinec, dipl. ing.

NASLOV RADA na hrv. jeziku:	Grafička reprodukcija flore s blizancima procesnih bojila u vidljivom i bliskom infracrvenom spektru
NASLOV RADA na engl. jeziku:	Graphic reproduction of flora with twin process colors in visible and near infrared spectrum

SAŽETAK:

Svaki dio flore ima svoju vrijednost apsorpcije svjetlosti u području vidljivog spektra. Otkrićem da procesne boje imaju razdvojenost u vidljivom i blisko infracrvenom (eng. NIR - Near InfraRed) dijelu spektra, postavlja se tvrdnja da je izvediva reprodukcija koja sadrži vlastite vrijednosti flore za oba područja. U radu se razvija metoda kojom iz flore uzimamo njenu NIR informaciju.

Cilj istraživanja je postizanje istog spektrograma flore i njene reprodukcije u vidljivom i bliskom infracrvenom spektru. Priroda ima vlastiti blisko infracrveni sadržaj pa je cilj istražiti kako izgledaju svojstva apsorpcije flore izvan vidljivog područja, uz definiranje svih parametara u procesu grafičke reprodukcije flore s blizancima procesnih bojila u svrhu dobivanja kvalitetnije reprodukcije.

Mjerenja su usmjerena prema izvođenju receptura bojila za reprodukciju flore te optimalizaciju broja blizanaca za kvalitetan otisak u vidljivom i NIR spektru. Istraživanja su se provodila u laboratoriju za forenzička ispitivanja materijala i boje, na uređaju za spektralnu digitalnu. Spektrofotometrijskom metodom mjerenja dobiva se kontrola nad segmentom testiranja uzorka koji nije vidljivo golim okom, a interval snimanja proteže se od 400 do 1000 nm čime smo obuhvatili vidljivi i blisko infracrveni dio spektra. Kao dodatna kontrola dobivenih vrijednosti mjerena je CIE L*a*b* vrijednost uzorka te se za svaku eksperimentalnu iteraciju računala ΔE vrijednost dok se nije postigla vrijednost manja od tri za pojedini blizanac. Teorija blizanaca boje razvijena je s primjenom na algoritam za spajanje dviju slika vidljivog i blisko infracrvenog spektra. Uspješnim izvođenjem matematičkog modela dobivene su vrijednosti blizanaca bojila iz flore koje su integrirane u postojeći algoritam, čime je postignuto proširenje i unapređenje INFRAREDESIGN® teorije za prikaz flore, a iz postignutih rezultata razvijene su metode koje vjerodostojno simuliraju tonove dobivene mjerenjem vrijednosti flore u NIR spektru. Time se postiže da nova grafička reprodukcija ima isti odaziv u NIR području, kao i original, flora.

Ključne riječi: flora, reprodukcija, blisko infracrveni spektar, INFRAREDESIGN®, blizanci bojila

ABSTRACT:

Each part of flora has its own light absorption value in the visible spectrum area. With discovery that process colors are separated in visible and near-infrared (NIR - Near InfraRed) part of the spectrum, a claim is being made that the reproduction that contains it's own flora values for both areas is feasible. In this paper a method is being developed by which NIR information is being taken from flora.

Measurements are aimed at producing dye recipes for flora reproduction and optimizing the number of twins for quality print in visible and NIR spectrum. The research was conducted in the laboratory for forensic examinations of materials and colors, on a digital spectral device. With the spectrophotometric method of measurement, we gain control over the test sample segment that is not visible to the naked eye, and the recording intervals extend from 400 to 1000 nm, which encompasses the visible and near-infrared part of the spectrum. As an additional control of the obtained values, the CIE L*a*b* value of the sample was measured, and for each experimental iteration a ΔE value was calculated until a value less than three for each twin was reached.

The color twin theory was developed with application to an algorithm for merging two images of the visible and near-infrared spectrum. By successfully formulating the mathematical model, the values of dye twins from flora were obtained and integrated into the existing algorithm, thus expanding, and improving the INFRAREDESIGN® theory for flora representation from the collected data in the NIR spectrum. This ensures that the new graphic reproduction has the same response in the NIR area as the original, flora.

The purpose of the research

Purpose of this study is to achieve the same spectrogram of flora and its reproduction in the visible near infrared spectrum. Nature has its own near infrared content, so the purpose is to investigate what do absorption properties for flora outside visible spectrum look like, while defining every parameter in the process of graphic reproduction of flora with twins of process dyes in order to obtain reproduction of better quality.

Research Hypotheses

1. CMYK process colors are adequate to simulate all colors of the visible spectrum, including infrared light absorption from flora.
2. By merging of two photographs in the visible and near infrared spectrum we can formulated an algorithm that credibly simulates all twin colors from the middle of the tonal spectrum that were obtained by measuring flora in the range from 400 to 1000 nm.
3. Graphic reproduction of flora with process dyes can be fabricated so that the range of coloring in the printing technique allows the same absorption in the visible and near infrared spectrum as in nature.

Scientific contribution of the proposed research

Improving INFRAREDESIGN® technology for realistic representation and flora printing with the extension of the dye twin theory and its application to an algorithm for merging two images of the visible and near-infrared part of the spectrum. Numerous measurements of flora samples were conducted, and with the information from spectrophotometric recordings of the samples information on the absorption of flora in both spectrums was obtained.
Experimental iterations were conducted on samples of the obtained dye twins until the value of the colorimetric difference between the individual twins fell below three. From obtained values of the dye twins that reproduce the color of the flora a database of the absorption properties of the flora samples was created. The database contains 59 twin dyes prepared for graphic reproduction of flora, which made this dissertation even more valuable and additionally contributed to the development of graphic technology.

A new mathematical model and algorithm for merging visible and near-infrared images and for determining the coverage distribution of dye process components in order to perform dual reproduction of flora was formulated. The development of an algorithmic solution for merging two images of different spectrum with an associated set of dye twins followed a properly performed image deformation in the NIR area. Seventeen dye twins were selected for this part of the experiment and undertaken for further analysis.
Development of the algorithm required the formulation of a mathematical model which was then integrated into the existing image merging algorithm. The mathematical model was formulated by regression analysis of the obtained values from the flora for K = 36. To perform mathematical interpolation, we created a twin of the same color shade as X_0 where K = 0, with a given value of K = 36, and it is represented by X_{36}.

The analysis defined the interdependence of these experimental values, and a formula that would perform mathematical interpolation algorithmically for the same pixel positions in the image for the visible region and the NIR region of the spectrum was derived. By successfully performing mathematical interpolation, the values of the dye twins from the flora were obtained and integrated into the existing algorithm, thus achieving the expansion and improvement of INFRAREDESIGN® technology and achieving the original scientific contribution.

New methods of graphical reproduction of flora have been developed that include the visible and near-infrared spectrum with the identification of the realistic state of the flora in the extended light range. As a result of all research in this paper, a graphical reproduction of the flora with twins of process dyes in the visible and near-infrared spectrum was produced.
The difference between standard flora reproduction and dual flora reproduction in the visible and NIR areas of the spectrum was experimentally determined. Although there is almost no noticeable difference in the visible part, the image in the NIR part shows a large deviation in the reproduction of this hidden area of the spectrum.
Successful reproduction of flora in two spectral areas finds its greatest application in the production of camouflage uniforms. And with the help of the created database that has absorption properties of flora samples, a uniform for all seasons can now be created.

Key words: flora, reproduction, Near InfraRed, INFRAREDESIGN®, twin dye

Zagreb, 21.07.2021.