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APPLIANCE OF TWINS AS A WAY FOR ACHIEVING SECURE HIDDEN IMAGE IN INFRARED TECHNOLOGY

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Summary

Utilizing the situation that except image in visual part of the spectrum can be broadened to near infra red domain that is observed instrumentally, near infra red technology stated its principles. Visual color management leads and controls both domains applying standard reproduction materials. CMYKIR separation principles allow attacking the secondary monochrome image to visual colored one, implementing achromatic principles. As the same color visual output can be performed on various ways, besides mathematical calculations, for accurate reproduction twin colors system is practiced.

Key words: *visual domain, near Infrared domain, color management, under color reduction, CMYKIR separation*

1. Introduction

Commercial graphic reproduction and its output devices use subtractive color system. As opposed to color film that uses three single subtractive primaries, graphic reproduction for achieving better quality applies the forth color, black [1][2], usually carbon black [3].
That includes the graphic system of four separations, screening, angles and other graphic arts features [4][5][6]. All that components are adjusted to visual domain, where image editing and manipulating tools/apps apply color management, that customizes (profiles) color and reproduction specifications to target output system [7][8]. As CMYKIR technology [9][10] uses only standard inks and materials, the whole process should be managed and controlled by common means. Input sources can be analog and digital, but for this purposes are usually prepared as digital systems, introducing RGB images of any kind, profiled as input source for visual domain. Secondary image, that will be as extended visible instrumentally only in NIR domain, is defined as gray scale. It must be stated that secondary image is not in a separate channel, already is incorporated in black channel.
Infrared technology systems can be applied in various application fields, not only printing and document valuables, currency, already leather, textiles, ceramic, art painting and all possible fields [11][12][13].

2. Transformations

There are several transformations and transfer functions that have to be accepted and applied in real reproduction process [14]. As the graphic production system is based on subtractive basic colors and black, a variety of colors (color responses) can be achieved on various ways.
Let us assume some principal situations:
a grey can be arranged from three basic primaries, transmission curves presented on Fig.1.
However, more or less of primaries amount will produce more or less intensity gray (N darker or lighter). As printing system use screening elements coverage, shown as CMY coverages, common area of cyan, magenta and yellow presents a neutral response and as a further step this common neutral area can be reduced with black ink coverage [15][16][17]. Broadening this case secondary, secondary colors red, blue and green (patches) when combined with their complementary primary components, form third, neutral (N) gray or black, if used as black, denoted as tertiar (K) color.
According to graphic color mixing principles this achromatic, and intensity modulating part, can be substituted with black. This principle can be broadened to a variety of colors when achieving different intensities. Basically a color changes to lower intensity, without changing hue (getting darker), adding its complementary component.
The common part can also be replaced with black.
Red, green and blue combination, as secondary

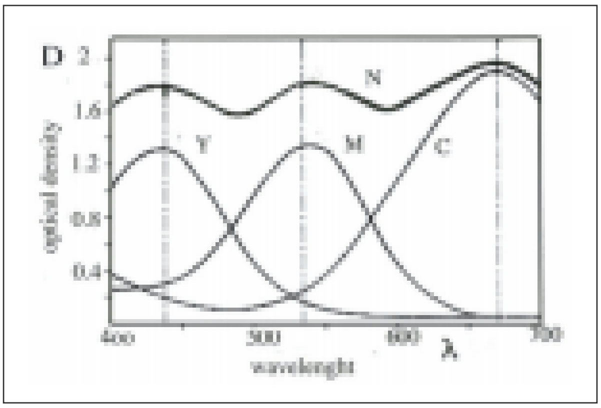


Fig. 1: *forming a neutral response using three basic CMY primaries*

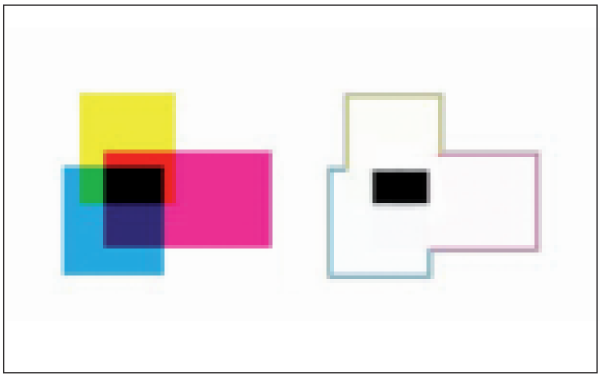


Fig. 2: *basic CMY forming visual neutral response, and possible replacing with black domain.*

color, get saturation increasing coverage, but adding complementary color (cyan for red, etc.) changes intensity. Red can be altered to red-black transition changing lightness (intensity) with complementary color. Hue should remain intact. Each place, spot, pixel of the image, remaining three primaries can be substituted with related black amount. This substitution allows multiple combinations, from maximal to possible minimal reduction amount. Starting point “a” is build from 100% M, 100% Y and 0% C coverage, and no reduction is possible. Point “b” consists approximately from 100% M, 100%Y and 60%C coverage. Some possible reduction combinations

Table 1: *some possible reduction combinations*

C %	*M %*	*Y %*	*K %*	*Combination rate*
100	100	60	-	Basic
40	40	0	60	Max. reduction
70	70	30	30	medium reduction

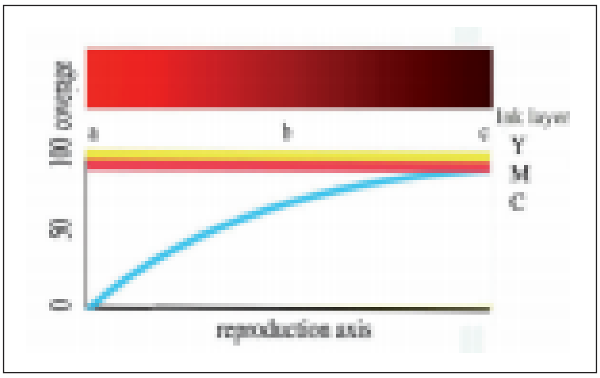


Fig.3: *changing property of red color lightness by a complementary color*

for “b” are presented in table 1. All possible combinations should, theoretically, remain same colorimetric properties. Point “c” is build from 100% M, Y and C, and could be entirely or partially substituted with black (K). Common tertiar combination can be substituted by achromatic, Fig 3.

3. Black ink conversions

Further important situation are responses of standard dyes in visual and NIR spectral domain. In visual CMY color responses vary according the reflection properties of the chemical and physical characteristics of a colored dye usually described through profile [18][19][20]. In NIR domain they are mostly rather high, similar as standard substrate. Carbon black (K) renders rather low reflection properties in both spectral domains, fig 4.

These responses are preserving the overall visual functionality of the system. Images as RGB or CMY(K) system, theoretically, should have the same appearance. Standard visual reproduction quality is guided through color management in the visual domain, and in NIR spectral domain chromatic colors appear near to substrate, and the black component according to Z-parameter [21] denotes secondary image that can be visualized instrumentally [22]. If system is balanced these two images do not interfere, secondary image is hidden for visual, and first, visual image cant be observed instrumentally.

Further step when implementing images is RGB to CMY(K) transformation. Input system perform an RGB image, mostly profiled, that has to be rendered to output system requirements. Basic PS RGB to CMY(K) (eq. 1) transformations are not directly acceptable

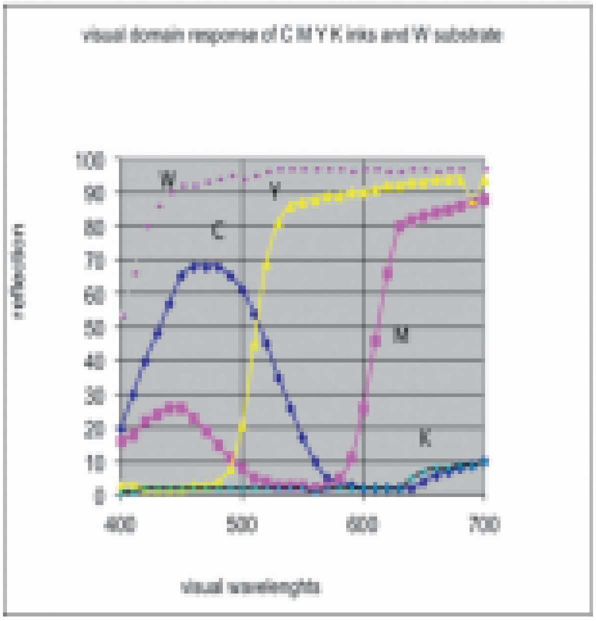


Fig. 4: *spectral responses of cyan (C), magenta (M), yellow (Y), carbon black (K) inks, and white substrate (W) in visual domain*

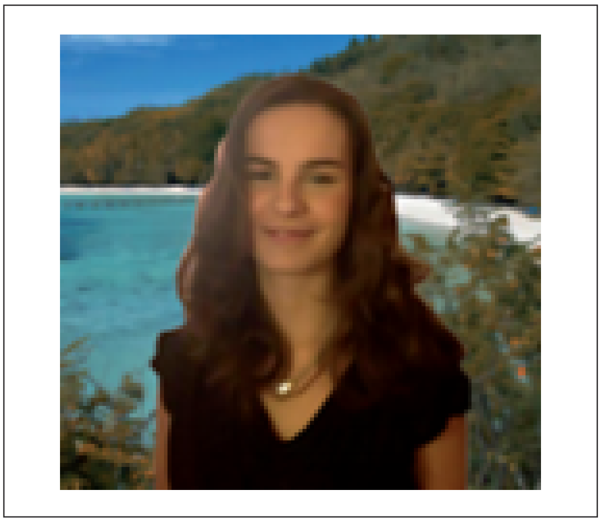
as they do not support specific reproduction parameters (profiles). Most separation systems, scanners and image manipulating apps generate black channel or black printer due to separate channel or superposing and combining existing separation channels.

$$C = 1 - R$$
$$M = 1 - G \qquad (1);$$
$$Y = 1 - B$$

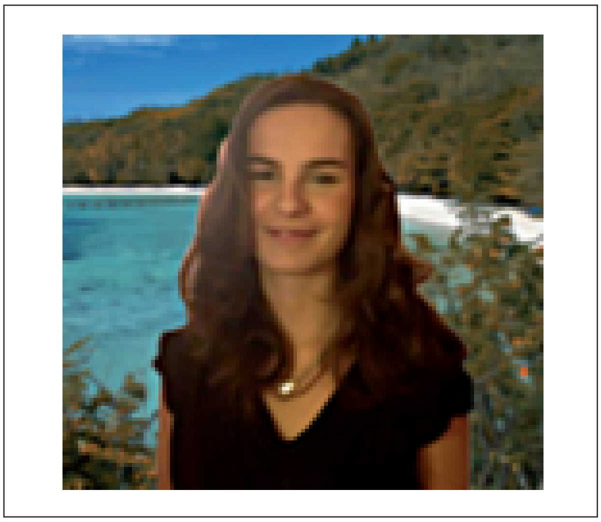
K printer value, or black channel principally is defined through existing CMY values along supplementary modulation of transfer curves, coverages etc.

$$K = f(\min(C,M,Y)) \qquad (2);$$

They are managed through CMM modules supported by ICC specifications, incorporated in image editing app [23]. Mostly a custom,



RGB image (screen)



CMYK image (print)

RGB image separation

CMY image separation

CMY+K image separation

Fig. 5: *image separations presented as RGB, CMY and CMYK color system*

dedicated profile has to be performed. As double achromatic substitution is unacceptable while attaching the second image while system black areas can remain, first step is defining pure or basic CMY system (eq. 2), that by attack can be transformed with black (K)

Cyan = Min(1, Cyan*(1-Black)+Black)

Magenta = Min(1, Magenta*(1-Black)+Black)

Yellow = Min(1, Yellow*(1-Black)+Black) (3);

4. Dedicated separation

As stated, subtractive reproduction system (model) is used in graphic reproduction and color photography. As opposed to color photography, graphic reproduction uses additional, forth color (channel) black, for improving the quality of the printed picture. According to subtractive principles three primaries combination form neutral visual response. This means, theoretically, that C, M and Y color filters of 0.3 density will produce achromatic response of D = 0.3 N (neutral), but also the some colored combination will decrease intensity of some color for that amount, practically two times. That principle adopted to graphic reproduction exposed as coverage (â) is widely used in various situations. For these considerations it is interested to modulate opposite or complementary color by changing intensity with black, and the possibility to change any tertiary subtractive combination with black. This reduces ink amount, improves picture quality and stability, expressing shapes better, and facilitates the situation that huge variety if tones and color can be expressed in various combinations, reproduced, but achieving the same visual response. Situation of Fig. 2 presents a “full tone or 100% tint coverage situation” but it can be, theoretical, presented as any equal situation.

Fig. 5 presents a RGB to CMY conversion. These are two different modes and colorimetric systems. Equations [1], [2] and [3] are theoretical PS equations, but unfortunately most transformations and transfer functions in real reproduction are not linear, but their attributes and features must be defined and accepted. This covers wide range od characteristics interconnected to reproduction system, input and output devices, substrate, ink, supplementary and additive materials, described as device profiles. Part of them, especially for print production, are defined as ICC profiles and ICC regulations, but some systems do not support them correctly, and variety of substrates are not covered with ICC, and some inks properties also do not fit the regulations (ICC).

According to stated facts an image can be treated as pixel matrix, where each picture element has its colorimetric values.

Pixels in basic mode should be analyzed. As example, it can be seen that A row could reduce low K component value, B row could produce higher amount, as shown on table 2. This indicates situation that each place of the image is not suitable for placing second hidden image.

This indicates that in K channel (as well K printer) these three observed pixels could be reproduced as K ink and be observed, Fig.9

It has to be stated that image is prepared in a dedicated way. The CMYKIR separation module [24] treats image in generic CMY mode. If there were any K values, they would be displayed as gray or dark pixels. It is evident the secondary image can not be placed anywhere, but on pixel places that allow reduction. On other side

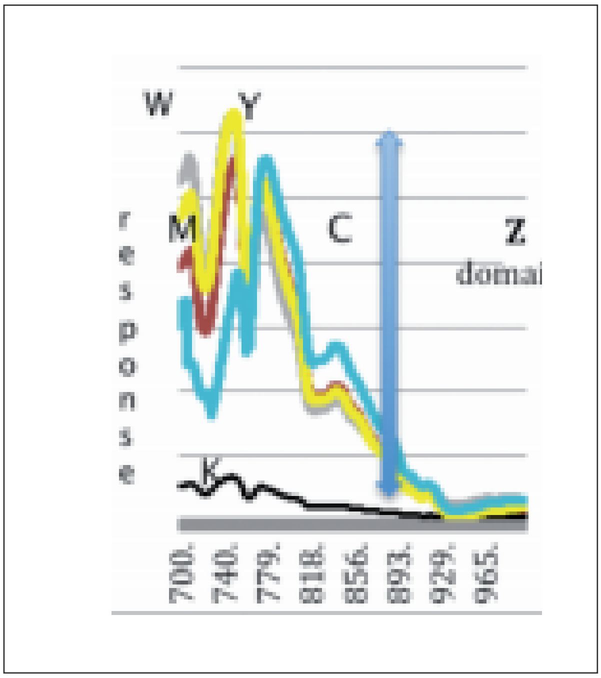


Fig. 7: *NIR responses of white substrate W, magenta M, cyan C and yellow Y ink, and carbon black K*

possible reduction pixel rate evidently varies from pixel to another. Color output in reduced stage must not differ from non-reduced one. This leads to profile usage. Standard ISO profiles often are not suitable when using different output systems using non recommended materials. It manifests that also highly custom profiles often do not fit exactly, specially in dedicated situations with particular tones and hues. Second, image manipulation apps color reduction treat as low, medium and high, and one option has to be chosen. As every pixel can have different color amount, that points out that secondary image could not be stable, and equable what harms second image quality. Neither standard profile tuning nor reproduction curves modulating improves that situation.

Image 8 presents cyan reproduction curve slope, in addition that magenta and yellow have different slope values, what is adversely for calculation. Solvation led to specific solving of the conversion system and performing regression analysis of reproduction CMY reproduction curves for achieving conversion values [25]

The specific problem, varying reduction amount that can occur between neighboring pixels while rendering was a specific task in CMYKIR separation module, and acceptable solution is found as fixed amount rate for all changeable pixels.

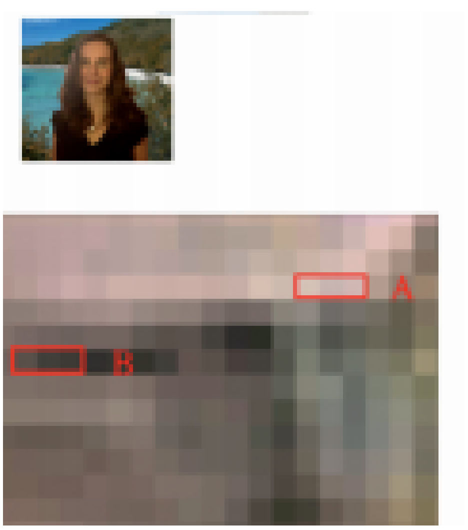


Fig. 8: *part of the image at pixel size in CMY mode*

Table 2: *selected coverage CMY pixel values of selected rows*

values	***1***	***2***	***3***
A	11 22 19	17 28 20	14 27 18
B	46 65 59	60 65 61	72 68 64

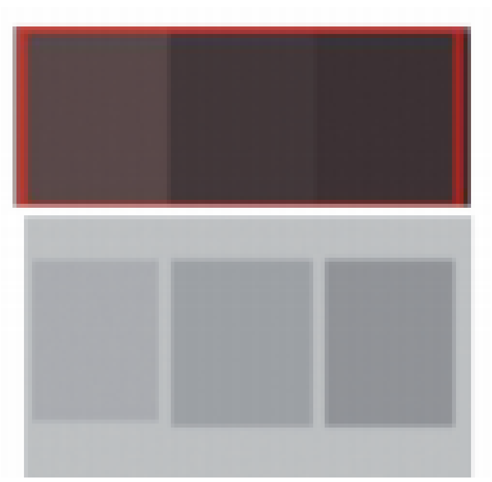
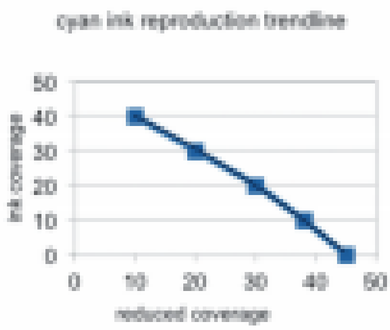


Fig. 9: *possible reproduction of B row pixels, visual, and as K values, and/or captured with Z camera*



Calculated trend line for cyan
$y = -0,0084x^2 - 0,6697x + 47,314$
$R^2 = 0,99943$

Fig. 10: *cyan ink trend line for selected dedicated separation reproduction system*

5. Twin pairs formation

In double image managing a situation could occur that conversed (reduced) and no-conversed color hue or intensity do not fit exactly on reproduction profile. That can produce various unwanted consequences, just to mention ghost image situation [26][27]. Dedicated configured profile sometimes also needs fine tuning. In case of outside captured image, standard color atlas fig. 11, would partially suit, but often be a complete, detailed, dedicated color atlas will be needed, that in practical situations often is not acceptable. In such situation only some specific or highly interesting colors could be separately treated. In a image that all colors are customized (fig. 12) practically each color has to be determined. Investigations showed that for high sensitive situations twins principle is needed. This includes the path from known or measured values of a color, its regression rendering and dedicated profile forming, and realization.

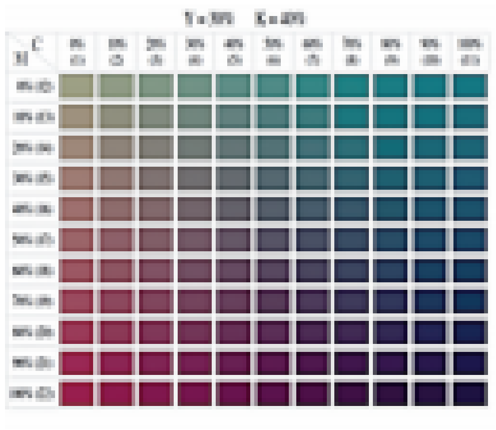


Fig. 11: *C, M, Y30, K40 combinations in the standard color atlas*

Due to certain non - accuracy to profiles of some output systems used, twin pairs have to be created. They attempt to perform stabile combinations of color patches of single CMY and reduced combinations with K, that are going to be basic for secondary - hidden image. It is important that their uniformity is high, expressed in colorimetric values, significantly under ΔE=3. That in practice contemporaneously ensures visual equality. Some primary defined twin pairs for selected output are shown on Fig. 11. Each twin pair is dedicated, separately chosen and recalculated for equality. Pairs rows are arranged due to some colorimetric parameter, hue, saturation or lightness [28].

In the process of adjusting pairs, as often in reproduction procedures, one of primary steps is checking the gray balance. That step is important for separation while he directly influences

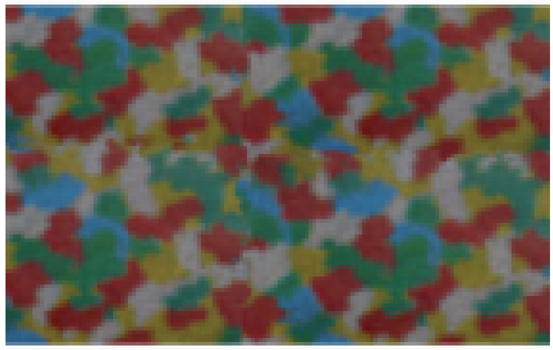


Fig. 12: *example of highly defined image color selection: camouflage colors,*

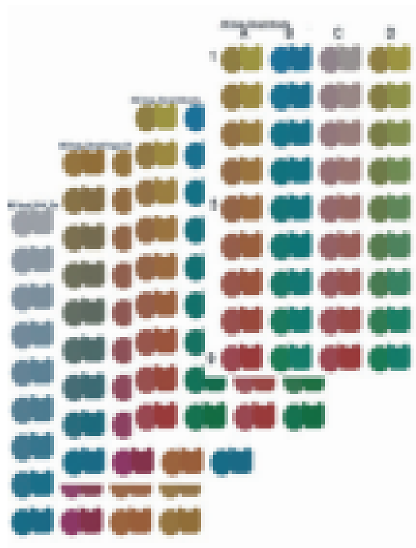


Fig. 13: *selected twin pairs series*

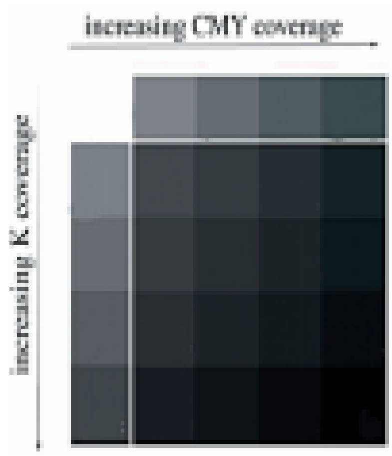


Fig. 14: *gray intensity with K combinations*

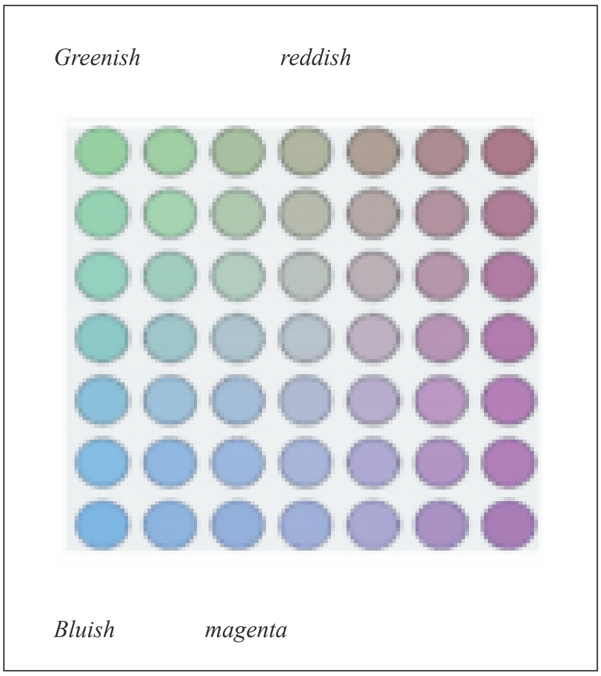


Fig. 16: *changing hue values from middle to corners in a slight increment*

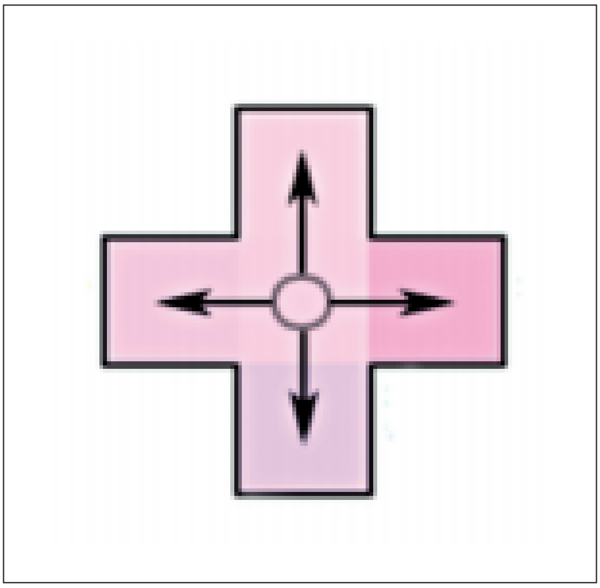


Fig. 17. *possible fine tuning of a target color in saturation and/or lightness change*

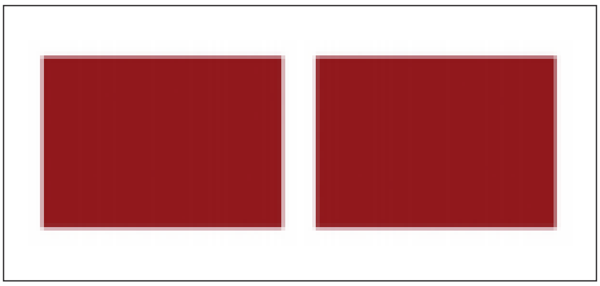


Fig. 18. *Generic (left) and reduced patch of bordo 56*

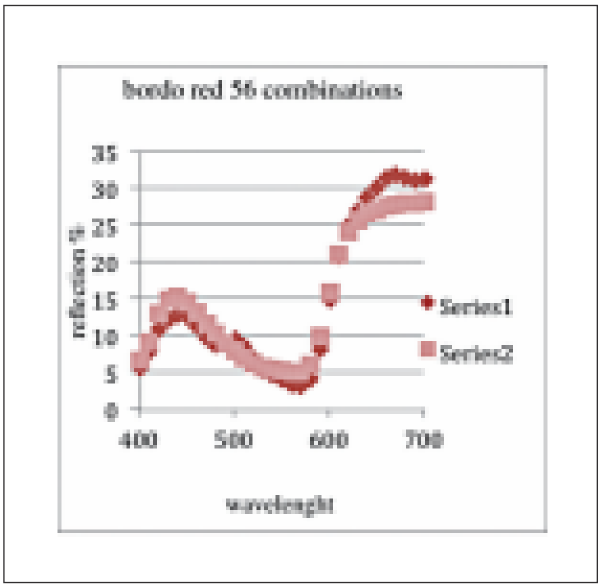


Fig. 19: *spectrophotometric curves of two defined (bordo red series 1 CMY, series 2 reduced version) colors of the similar response*

properties of secondary hidden image, when portion of CMY is changed or compensated with black, region where observers visually are very sensitive.

These combinations are very sensitive while increments are rather small, 2 or 3 % coverage. This is a reproduction challenge, but stabile output devices can perform this, and measurements can be carried out secure. Some additional test can eventually be made for some specially sensitive situations, as shown on fig. 13, where target color is in the middle of the test, and possible tolerance variations in up-down and left right direction in a small increment.

Result of tuning for two bordo red colors in CMY and reduced mode is shown on Fig. 14, where series 1 is CMY combination and series 2 reduced combination. Colorimetric delta value is 1.7. Optically they perform the nearly the same optical response Fig 18. and measured curves almost overlap, Fig 19.

6. Conclusion

CMYKIR separation and performing a secondary hidden image is very sensitive process. Practically each color or colored pixel must exist in two stages, basic CMY and a converted combination with K. Both basic combinations visually must have the same visual response. As the whole process starts in visual, and visual color management controls both domains, visual and NIR, dedicated settings in most cases have to be performed. Black channel and under-color settings are the carriers of the hidden image, and only black component (K) according to **Z** value principles will the second image enable to be detected. Adjusting color cast, specially custom colors involves custom profiles calculation, measurements, and visual validation. In some cases numerous additional tests have to be performed. The separation output module is specially developed and adjusted for such complex purpose.

Regardless to complexity of the process, this method developed extended separation principles, expands overall functionality of color management, and opens the wide possibilities to designers [29], engineers [30], and innovators [31] in a variety of fields to create new products, security applications [32][33], individual art items [34], and products and processes in unlimited ways.

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PRONALAŽENJE SKRIVENE INFORMACIJE U INFRACRVENOM SPEKTRU NA SLIKAMA U SAMOSTANU KAMELIĆANA U REMETAMA I U PRIVATNOJ ZBIRCI U ZAGREBU

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Sažetak

U ovom su radu izdvojene dvije slike u vizualnom i bliskom infracrvenom području od 1426 fotografiranih u sedam muzeja, tri zbirke, deset povremenih izložbi i pet privatnih zbirki u Zagrebu. Na slikama koje se prikazuju otkrivena je u cijelosti preslikana slika i preslikani sloj, što je tema ovog rada. Umjetničke slike imaju dva odvojena stanja slike u različitim spektralnim područjima. U članku će biti prikazane razlike između tih dviju slika prilikom snimanja u dva spektralna područja RGB kamerama.
Pri istraživanju je korištena ZRGB kamera koja snima u vizualnom i u bliskom infracrvenom (NIR) spektru na Z vrijednosti [1]. Cilj istraživanja bio je utvrditi stanje slike u bliskom IR području kako bi se uočili preslikani podaci u sloju ispod vidljive slike koji su nevidljivi golim okom. Prijedlog je da konzervatorsko-restauratorski postupci respektiraju dva stanja slike i da se slike fotografiraju u bliskom IR-u i nakon radova. Rezultati provedenih istraživanja dio su doktorske disertacije na temu *Slike u infracrvenom području – odlaganje vidljivog.*

Ključne riječi: *vizualni i infracrveni spektar (NIR), slike u infracrvenom području, preslikani sloj, ZRGB kamera*

Abstract

In this work, two paintings photographed in visual and near infrared (NIR) area are selected among 1426 photographs taken in seven museums, three collections, ten temporary exhibitions and five private collections in Zagreb, Croatia.
The topic of this work is the paintings discovered underneath these two paintings. Therefore, the paintings have two separate conditions in different spectral areas. The article shows the differences between these two images in these spectral areas using RGB cameras. Here, a ZRGB camera was used, which records visual and NIR spectra on Z value [1]. The aim of this research is to determine the conditions of the paintings in NIR spectrum to find the overlapping data in the layer underneath the visible painting, which are not visible to the naked eye. It has been proposed that the conservation and restoration procedures take into consideration these two conditions of the image, and that the paintings be photographed in NIR after the restoration. The results of the research are part of the doctorate thesis on the topic: *Paintings in the infrared area – postponing the visible.*

Key words**:** *visual and infrared (NIR) spectra, images in the infrared area, painted layer, ZRGB camera*

1. Uvod

IR svjetlost rasprostire se od 700 do 30000 nm i dijeli se na nekoliko područja. U hrvatskom jeziku koriste se definirane kratice IR (engl. *infrared*) i IC (*infracrveno*). Termin koji se koristi u konzervatorsko-restauratorskoj struci pri snimanju umjetnina naziva se IR reflektografija. U ovom radu označeno je kraticom NIR (bliski infracrveni spektar ili *near infrared*), a zauzima raspon od 700 do 1400 nm. Koristimo NIR područje zato što su u tom dijelu napravljene digitalne kamere opće namjene s CCD senzorima. Unutar ovog bliskog infracrvenog spektra istraživalo se područje na 1000 nm. Točku na toj određenoj valnoj duljini zovemo Z [2]. Ispod površine slike Pabla Picassa *Plava soba* iz 1901. IR reflektografijom pronađena je, u lipnju ove godine u Washingtonu, skrivena slika *Portret nepoznatog muškarca*. Povjesničari umjetnosti i stručnjaci bave se otkrivanjem tajne tko je tajanstveni lik ispod površine slike, zašto ga je umjetnik preslikao