ORIGINAL SCIENTIFIC PAPER
RECEIVED: 31-08-2012
ACTA GRAPHICA 205
ACCEPTED: 19-09-2012

New Postage Stamp Design With Tone Gradation in Infrared Design Technology

Authors

Maja Rudolf[1*], Tajana Koren[1], Jana Žiljak-Vujić[2]

[1]*University of Zagreb, Faculty of Graphic Arts, Croatia*
**E-mail: mrudolf@grf.hr*

[2]*Polytechnic of Zagreb, Croatia*

Abstract:

This paper deals with the application of new steganographic methods in postage stamp printing technology with the goal of securing them against counterfeiting. Postage stamp designs are presented which contain double information in the visible and in the infrared spectrum area. New methods include printing with process printing inks that have a continuous response in the infrared area of the spectrum. The infrared Z image cannot be produced with conventional CMYK separation in such a way that the hidden picture does not show through when looking at the print. This is the reason for introducing CMYKIR separation, with mathematical relations that respect printing ink characteristics in the RGB to CMYKIR system conversion.
A mathematical model with targeted separation characteristics is proposed, with seven independent variables. It has been created as the result of optimal regression model developed on the basis of colour tone measuring for the visual and infrared spectrum. A technological procedure has been elaborated for producing and printing based on such designs. It is possible to detect the infrared image with the help of a device – the infrared ZRGB camera. Counterfeiting is impossible due to the irreversible conversion of the CMYKIR separation into the RGB system applied in contemporary scanners or cameras.

Keywords:

Postage Stamp, Double Image, CMYKIR, Infrared Technology, Z Parameter

1. Introduction

A postage stamp is a document that has a certain value and as such its design and technological production must be in accordance with the highest production standards. Postage stamps also have numismatic value when collected by collectors which can exceed their actual production value several times. A postage stamp is also a work of art with a motif that is linked with a certain event or is issued with a special theme. It is important to take special care with respect to postage stamp security in order to maintain their authenticity. Contemporary postage stamps are mostly printed in offset, a technique that does not provide an adequate security level, so additional security techniques are almost always used (*Vuèetiæ, 2011*). In the struggle against counterfeiting, it has become clear that a method should be devised which allows the possibility of hiding information that will not be reproducible with conventional printing methods. In this respect the infrared area has not been used sufficiently. The small size of stamps does not allow the artist much space. it It is therefore interesting to experiment with double information that will contain different graphics in the same area and at the same time provide security against counterfeiting.

This paper presents the design and print of three postage stamps with images for the visual spectrum and images for the INFRAREDESIGN technology (*Žiljak V., 2009*). In the printed version of this paper an original postage stamp, produced exclusively for this occasion, has been attached as proof of the claims set forth. Stamp security has been improved significantly because there is no possibility of reproducing such a print with conventional methods of scanning and repeated printing.

The infrared message is invisible to contemporary scanning methods because it is impossible to detect the CMYKIR separation. When the print with the hidden Z picture is scanned, it is converted into the RGB colour system, removing the information as to which colour was created physically, i.e. what quantities of cyan, magenta, yellow and black are present in the print (*Koren, 2010*). In this way the hidden infrared information created on the basis of the CMYKIR separation method is deleted too. The paper provides mathematical excerpts for planning colour tones with an infrared response and all claims on hidden information are proven by printed postage stamps with double images.

2. The theory on infrared color

Postage stamps printed with conventional printing inks are not considered as well secured by their properties. A good quality reproduction in the visible spectrum is not usually found on postage stamps printed mostly with process inks. A postage stamp as a security requiring product must be in accordance with high security standards, so it is proposed to carry out printing with inks that have a special property and that is response in the infrared spectrum area.

It is a well known fact that equal quantities of cyan, magenta and yellow components produce a certain shade of grey. This grey will not have a response in the infrared spectrum part, while its equivalent in the black component will have a response in the infrared area (*Žiljak, 2009*). Since a color shade can be obtained in several different ways by adding or subtracting the black component depending on the necessity and the adequate addition or subtraction of CMY components, one shade of any color can have a controlled response in the infrared area (*Žiljak V., 2012*). The technology named INFRAREDESIGN is based on this theory (*Žiljak I., 2008*) and it can significantly improve postage stamp security.

When producing stamps, colorants first need to be planned and tested for specific printing conditions (because of the nature of the very inks), due to the fact that the same CMY components will not always give a satisfactory shade of the grey component (*Koren, 2010*). When applying conventional methods, the separation can more or less precisely provide the subtraction of C, M and Y towards the K component. Each merging of paper with physical colorants has its own color-setting system at disposal, in respect to the colors which an infrared response should be planned with.

CMYKIR separation is based on developing the separation coefficient (*Žiljak V., 2009*; *Mccann*, 1998), studying the behavior of colorants in the near infrared area (*Vila, 2007; Žiljak, 2012*) and the fact that CMYK process inks are dependent on the type of printing technology and type of material (*Yousaf 1995*; *Žiljak I., 2008),* maintaining the quantity of the colored background, and thereby the reproduction quality (*Chen 2008*, *Žiljak I. 2008).* Such mutual relations have not been researched to the necessary extent, nor have the mathematical models been published that correspond with real-life colorant separation *(Žiljak V., 2011)*.

Double values of colors with a Z parameter

A new colorant category is introduced, the so-called Z-colorants (*Žiljak V., 2012*) that are described to have light absorption power at 1000 nanometers. The Z value of each colour can be planned to range from zero to one. That number marks the quantity of absorption in the IR area where zero marks 0% light absorption, and number one marks 100% absorption. Each color shade (in the visible part of the spectrum) can be obtained with an endless number of CMYK components, where a Z value is set for the specific colour tone in question, ranging from zero to maximum. If there are at least two colours with an identical colour tone but with differently marked Z values, it is possible to create a hidden image. When designing a postage stamp, a continuous gradation of Z value in the IR spectrum is linked with a particular colour tone.

Security documents that have been printed up till now with IR security have a limited IR response, i.e. there are no multiple tone gradations in planning and production (*Žiljak I., 2008*). In the case of postage stamps, the proposal is to introduce multiple tone images with different IR characteristics.

Experimental postage stamp prints have been carried out in offset printing with planned design and Infraredesign technology that consists of hiding the infrared picture inside the picture visible in daylight.

3. Planning the design of a postage stamp with a hidden image

Examples of postage stamps that contain a hidden picture visible in the IR spectrum part are stamps linked with specific events, having therefore, specific motifs describing the occasion, and the visible and the invisible pictures are thematically linked with each other.

Two sports events have been chosen as the motif in the first stamp celebrating the success of Croatian skiers Janica and Ivica Kostelić. The motif in the visible part is the image of Janica Kostelić. The text under the picture contains the name of the skier and the occasion: celebrating the tenth anniversary of her winning a gold medal at the Salt Lake City Olympic Games. The text is in two colors, purple and grey, planned and designed to provide a different response in the infrared spectrum part.

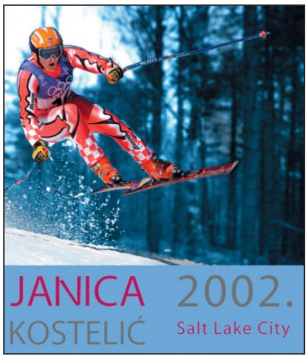


Figure 1. The design of the new postage stamp for the spectrum visible part

In the prepress phase a design is made using conventional software that is applicable in the usual process of preparing pictures for printing. Figure 1. shows the design in the conventional CMYK system for an image visible in daylight. The second phase is preparing an additional image together with the design for the visible spectrum part. The additional image will be visible in the IR spectrum part. The input IR message is prepared as a black-and-white picture with a certain black color maximum, estimated for infrared response.

Figure 2. The invisible Z message design to be embedded in the visible picture

The motif of the hidden image is a picture of Ivica Kostelić, with a corresponding text that contains his name and surname and the information about the occasion celebrating his winning of the *Mali kristalni globus 2012* award (Small crystal globe 2012 award). There is an overlapping of the motif and the text in the visible and in the hidden pictures. Parts of the text having the same colour tone in the visible spectrum must show different light absorption in the infrared spectrum, resulting in different levels of black ink coverage. The initial CMYK image has zero value in the K channel.

4. Mathematical model of CMYKIR separation

The additive RGB colours by which an image is described in our eye equals the subtractive CMY colour system that is used in the printing industry for the reproduction of colours of the visible spectrum. Those two systems are complementary and in conventional theory they are set by the following relation:

$$C_0 = 1.0 - R_0$$

$$M_0 = 1.0 - G_0$$

$$Y_0 = 1.0 - B_0$$

The addition of the black component and the corresponding subtraction of the CMY components enables to produce one colour tone with different light absorption in the infrared spectrum, with the goal of producing two independent pictures in one print (*Pap, 2010*). The black component of one colour tone can acquire a random value between zero and K_{max}.

$$K_{max}=Min\ (C_0, M_0, Y_0\ )$$

However, these formulas do not function in the real-life world of physical colorants. Process inks produced by different producers are not quite the same. If the mixing of colorants in practice is done according to these simple formulas, the results obtained are almost never unambiguous. There is no possibility to achieve a satisfactory level of hiding the infrared image if applying them in practice.

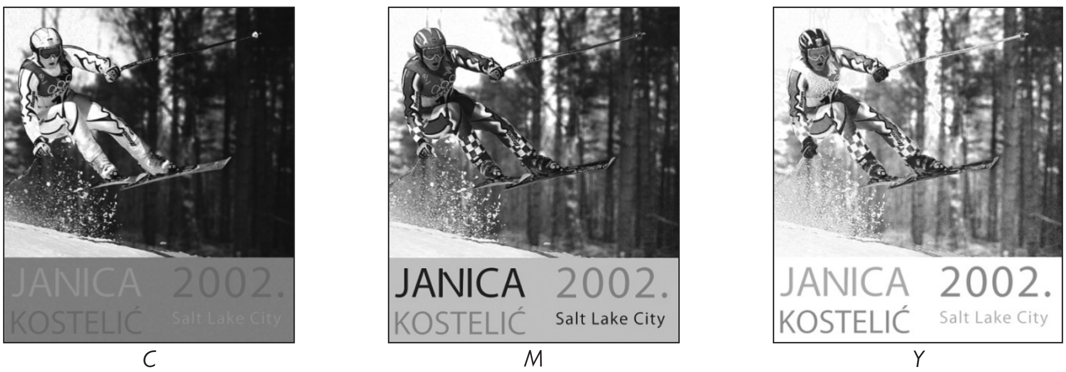


Figure 3. Conversion phase of the conventional CMYK image into CMY with K = 0

The described procedure creates a base for a CMYKIR separation algorithm created to make estimates for a new colour with a response in the IR spectrum part by combining CMY data (with K=0) and input IR values at necessary points. Such separation is carried out for known printing conditions, i.e. formulas for calculating quantities of certain components are adjusted in respect to the print type and colorants with which the print is made.

In order to achieve steganography, it is necessary to adjust the colour-setting for a particular printing technology, inks and materials. The GCR conventional separation is abandoned by introducing CMYKIR separation. CMYKIR separation uses the exterior Z image as the desired level of GCR value participation for each pixel itself.

When converting colours from the RGB system into the CMYK system, what follows is that the HSB or Lab values will not change for a certain colour in the RGB system, whereas CMYK component values will be different in the area from K = 0 to maximum K value that the corresponding colour can achieve in the observed pixel.

In this paper a mathematical model is set through dependency of $X_{1/2}$ and X_{max} to X_o; X representing the tone of one color that can achieve Infrared effect. Analytical relations for the Euro scale, uncoated process ink system and printing paper for printing postage stamps are given for CMYKIR separation.

$$X_{max} = D_{max} * E$$

$$X_{\max} = \begin{pmatrix} C_{\max} \\ M_{\max} \\ Y_{\max} \\ K_{\max} \end{pmatrix}; E = \begin{pmatrix} C_0 \\ M_0 \\ Y_0 \\ Z_3 \\ Z_2 \\ Z_1 \\ 1 \end{pmatrix}$$

$$D_{max} = \begin{pmatrix} 23,37 & 3,678 & 3,518 & 0,1812 & -1,035 & 1,535 & -83,29 \\ 3,304 & 2,952 & 10,91 & -0,047 & 1,268 & -0,773 & -38,43 \\ 24,52 & -5,862 & 7,912 & 1,923 & -1,397 & -0,215 & -57,50 \\ -12,50 & -1,962 & -6,254 & -0,120 & 0,476 & 0,184 & 56,35 \end{pmatrix}$$

Where:

$$Z1 = Co3/ S;$$
$$Z2 = Mo2*Co/ S;$$
$$Z3 = Co * Mo * Yo / S;$$
$$S = Co + Mo + Yo$$

In the same way dependencies of C, M, Y and K values are set at half value of K_{max} through matrix H with the same structure of matrix E.

$$X_{1/2} = H_{max} * E$$

$$H_{max} = \begin{pmatrix} 5,682 & 1,791 & 0,227 & -0,014 & -0,243 & 1,242 & -27,18 \\ -0,346 & 1,253 & 4,361 & -0,024 & 1,211 & -0,291 & -17,92 \\ 5,489 & -3,595 & 4,373 & 1,475 & -0,369 & -0,193 & -23,49 \\ -6,325 & -1,014 & -3,129 & -0,059 & 0,239 & 0,089 & 28,25 \end{pmatrix}$$

After estimating $X_{1/2}$ and X_{max} values, then the X_o to X_{max} values are estimated per circular segment approximation:

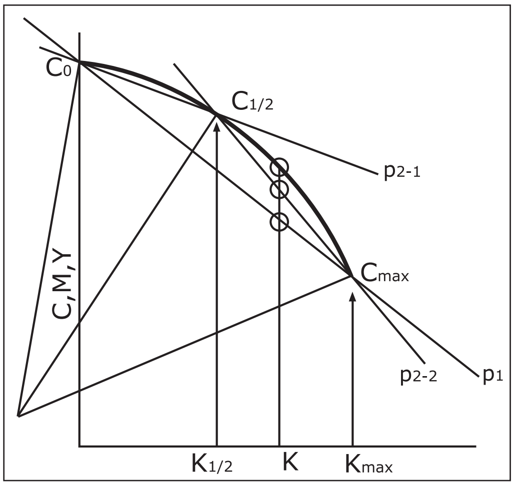


Figure 4. Linear and circular approximate values between X0, X1/2 and Xmax

Numerical values in matrix D and H are derived by means of a multiple regression analysis from measuring a wide range of CMYK status combinations (188 measurements for each CMYK channel) (*Koren, 2010*). The values are comprehended as the maximum and its average, while maintaining La*b* parameters for the visual spectrum.

C M Y K

Figure 5. Single channels of a picture that has undergone CMYKIR separation

Figure 5 shows the results of channels made by CMYKIR separation. The difference in mixing the same colour tone with a different response in the IR spectrum is best observed in the text part. The name "Janica" is set in the visible spectrum part in one tone of lilac. The first two letters must not respond under infrared light, whereas the remaining part of the text has a certain amount of IR response and changes into the name "Ivica".

It is clearly observed in the Figure 5 CMYK channels that this same lilac tone had been created with different mixing of the basic components, where the colour tone for the first two letters are set with CMY components only, whereas the K value had been added to the remaining letters with the corresponding subtraction of CMY components.

The same principle of adding black and subtracting CMY occurs with the remaining text and the hidden picture.

a) b)

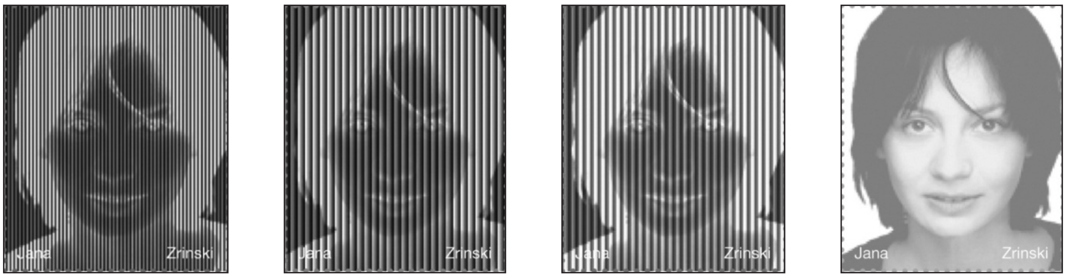
Figure 6. Real-life print of two stamps in the visible spectrum (a) with a hidden image (b) in offset

The lower postage stamp in Figure 6 represents an abstract linear structure in the visible part of the spectrum, but under infrared light the portrait of the co-writer of this paper is visible. The reason for making such a design is to research the dependency of a certain type of graphic in hiding information. Vector lines in the visible part of the spectrum are made in various colour tones for which a continuous Z value had been estimated. The graphic was designed in such a way that it has a gradation of response in the infrared message from zero to maximum, and this was necessary in order to produce the output portrait picture.

Figure 7 shows CMYKIR separation for a postage stamp with a linear graphic in the spectrum visible part and a portrait in the hidden message of the black channel.

The third example of a printed postage stamp is designed on the occasion of the international innovation exhibition in Romania. The hidden portrait is again the picture of the co-writer of this paper, as she had been the one presenting the INFRAREDESIGN innovation at the exhibition. Together with the corresponding typography, the visible and hidden motifs have thereby been set in such a way that they are related to each other. Figure 8 a) shows Count Dracula's castle and figure 8 b) shows the image that is revealed under infrared light; the portrait of the co-writer and the text „Tajana & Dracula".

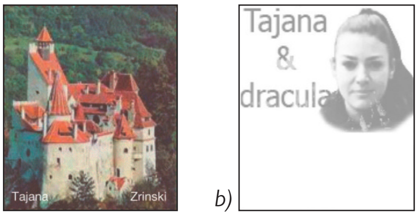
The picture described is used as the design for a commemorative postage stamp. The same as at the innovation exhibition, this is a case of a double image; one that is visible to the human eye and the other visible only in the infrared



C *M* *Y* *K*

Figure 7. CMYK channels of a picture that has undergone CMYKIR separation

spectrum part with the help of an instrument. The goal is to provide protection against counterfeiting. Figure 9 shows CMYKIR separation for the stamp in all channels. In this example, as in the first two, the image that is visible under infrared light demonstrates a continuous gradation of tone which was achieved with the calculations of the Z parameter characteristic for the offset printing technique.



a) *b)*

Figure 8. Postage stamp in the visible spectrum with the planned Z picture

5. Conclusion

A novelty in regards to the previous research in this area is a calculation of CMYKIR separation coefficients that match the printing environment of postage stamps. We are also developing a multiple tone gradation in the Z area, applied on postage stamps, which has not yet been achieved in any current document with an Infraredesign protection. Two separate pictures are designed for the double picture, one for the visible spectrum part and another black-and-white for the IR spectrum. The colour tones are planned separately and adjusted for the printing machine colour-setting in order to obtain a hidden picture integrated into the visible picture in the best possible manner. CMYKIR separation is carried out during prepress for the colours with which the hidden picture is merged with the visible one.

An algorithm is set for new separation values by respecting the security paper, the printing technique and the process ink properties when providing for the postage stamp security status. Security against counterfeiting has been achieved by eliminating the possibility of converting the printed picture into the RGB system (by scanning, photographing, or similar), and then printing it once again in such a manner as to keep the information of the infrared graphic. The analytical relation in creating a double picture has been achieved by devising the best model for the regression procedure. The proposed model has seven independent variables as a combination of the zero status with three process inks, with a conventional manner of separation.

C *M* *Y* *K*

Figure 9. CMYKIR separation in CMYK channels

References

CHEN, Y.D., BERNS, R.S., TAPLIN L.A., IMAI, F.H. (2008) "Multi-ink color-separation algorithm improving image quality", Journal of Imaging Science & Technology, 52(2), pp. 71-79

KOREN, T. (2010) "Razvoj steganografije u tipografiji sa stohastičkom raspodjelom infracrvenih boja", doktorska disertacija, Grafički fakultet, Sveučilište u Zagrebu

MCCANN, J.J. (1998) "Color theory and color imaging systems – past, present and future", Journal of Imaging Science & Technology, 42(1), pp. 70-78

PAP, K., ŽILJAK, I., ŽILJAK-VUJIĆ, J. (2010) "Image Reproduction for Near Infrared Spectrum and the Infraredesign Theory", The Journal of imaging science and technology, 54 (1), pp. 1-9

VUČETIĆ J. (2011) "Zanimljivosti kod novih hrvatskih redovnih poštanskih maraka", Zadarski filatelist [Online] 14, pp. 14-16

VILA, A., FERRER N., GARCIA J.F. (2007) "Chemical composition of contemporary black printing inks based on infrared spectroscopy: Basic information for the characterization and discrimination of artistic prints", Analytica Chimica Acta, 591(1), pp. 97-105

YOUSAF, M. AND LAZZOUNI, M. (1995) "Formulation of a invisible infrared printing ink", Dyes & Pigments, 27(4), pp. 297-303

ŽILJAK I., PAP, K., ŽILJAK-VUJIĆ J. (2008) "Infraredesign", Zagreb: FotoSoft

ŽILJAK, I., ŽILJAK-VUJIĆ, J., PAP, K. (2008) "Colour control with dual separation for daylight and daylight / infrared light", Enlund, Nils ; Lovreček, Mladen (eds), Advances in Printing and Media Technology 35, Valencia, Spain: International Association of Research Organizations for the Information, Media and Graphic Arts Industries, pp. 273-278

ŽILJAK, I., PAP, K., ŽILJAK-VUJIĆ, J. (2009) "Infrared design on textiles as product protection", Tekstil, 58(6), pp. 239-253

ŽILJAK, V., PAP, K., ŽILJAK, I. (2009) "CMYKIR security graphics separation in the infrared area", Infrared Physics and Technology, 52(2-3), pp. 62-69

ŽILJAK, V., PAP, K., ŽILJAK, I. (2010) "Infrared hidden CMYK graphics", Imaging science journal, 58(1); pp. 20-27

ŽILJAK, V., PAP, K., ŽILJAK-STANIMIROVIĆ, I., ŽILJAK-VUJIĆ, J. (2012) "Managing dual color properties with the Z-parameter in the visual and NIR spectrum", Infrared physics & technology, 55(4), pp. 326-336