# Hidden Messages with Pigments in Dual Print for a Visual and Infrared Spectrum

Vilko Žiljak, Lidija Tepeš Golubić, Jana Žiljak Gršić and Denis Jurečić

***Abstract*—**We are demonstrating an innovation in safety technology by solving dual information for a visual and Near InfraRed spectrum. We have hidden the messages in day-to-day life situations, in offices, halls, classrooms, on the theater stage. NIR technology enables us to use double ZRGB cameras to hide and recognize the wanted information realized in a few different media. What is invisible to the naked eye becomes visible with a new visual procedure of double recording. We are publishing new recipes for pigment mixing for painting on canvas and paper materials. Light absorption properties are being respected in two areas through the twin dyes theory. The results are being demonstrated as safety print on clothes, documents and protection of artwork in painting.

***Keywords*—**Infraredesign, hidden images, twin colors, recipes for pigment, infrared art.

## I. Introduction

OUR research has been directed to the technology of hiding information in the visual scope based on material carriers; paper and canvas. Graphics print, reproduction of the painting is being demonstrated in two light areas: visual (RGB, V) and near infrared (NIR – part Z). INFRAREDESIGN (IRD) is based on using dual dyes [1]. Twin dyes are two or more dyes that have the same color in the visual spectrum and different characteristics in the near infrared spectrum. New color tones are given in the article (table 1) for digital print on the plotter. Application is the print on white and black canvas [2].

IRD prepress is being performed with screens that do not have regular geometric shapes. IRD is being applied in safety graphics [3]. IRD uses mathematical mode of screening that are being used for individualized solutions, unique, protected. Prepress algorithms are being performed in the graphic language PostScript [4]. In this paper screening equations are being shown in a conventional language of mathematics, programming relations in C++, Python languages… and in PostScript code.

The first three columns in Table I are C0, M0, Y0: color twins for cyan, magenta and yellow without carbon black (K = 0) (in percent). Measured data for colorants with 40 percent carbon black are C40, M40, Y40. The data obtained with regression analysis are: C40r, M40r and Y40r. These data are the basis for programming textile dye separation.

Table I Recipes of twin colors and dyes

| C0 | M0 | Y0 | C40 | C40r | M40 | M40r | Y40 | Y40r |
|---|---|---|---|---|---|---|---|---|
| 33 | 33 | 33 | 7 | 14.74 | 1 | 6.25 | 2 | 1.10 |
| 43 | 95 | 90 | 2 | 2.78 | 77 | 74.05 | 65 | 62.13 |
| 44 | 81 | 42 | 17 | 17.31 | 72 | 65.63 | 8 | 14.47 |
| 41 | 39 | 86 | 18 | 17.34 | 4 | 8.83 | 71 | 63.20 |
| 34 | 95 | 52 | 0 | 1.47 | 84 | 87.60 | 36 | 29.32 |
| 99 | 43 | 40 | 90 | 94.70 | 2 | 2.61 | 2 | 9.45 |
| 99 | 99 | 99 | 77 | 76.95 | 62 | 64.22 | 81 | 77.33 |
| 61 | 35 | 51 | 48 | 45.37 | 2 | -1.29 | 21 | 18.46 |
| 43 | 99 | 100 | 0 | 1.37 | 76 | 77.33 | 67 | 74.06 |
| 44 | 92 | 38 | 22 | 16.54 | 89 | 81.80 | 7 | 12.78 |
| 88 | 59 | 23 | 85 | 83.19 | 24 | 27.53 | 0 | -4.01 |
| 70 | 56 | 36 | 62 | 55.86 | 23 | 25.93 | 7 | 4.96 |
| 45 | 40 | 30 | 30 | 30.86 | 9 | 11.18 | 0 | -0.29 |
| 80 | 32 | 75 | 71 | 72.19 | 0 | -9.40 | 45 | 53.03 |
| 97 | 55 | 22 | 93 | 94.10 | 18 | 19.22 | 0 | -7.22 |
| 30 | 76 | 77 | 0 | -1.44 | 59 | 62.08 | 53 | 58.31 |
| 35 | 35 | 35 | 12 | 16.62 | 5 | 8.00 | 5 | 3.41 |
| 50 | 38 | 99 | 35 | 32.19 | 7 | 3.65 | 78 | 83.20 |
| 45 | 55 | 99 | 24 | 24.50 | 22 | 24.41 | 90 | 85.16 |
| 45 | 48 | 99 | 26 | 25.43 | 18 | 16.48 | 87 | 84.81 |
| 50 | 58 | 99 | 31 | 31.49 | 29 | 25.86 | 79 | 86.03 |

## II. Model GRID-M of Screening in Safety Graphics

New screens as a mathematical creation are being introduced. Hiding of information, picture is based on the idea of twin colors [5]. It is difficult to achieve the equality of tones of colors that have different components. A screening technique is used in the microstructure of printing. The improvement of the idea of "hiding" is being achieved with screens that do not have regular microstructures. We have lucky time in which we define the most various screens based

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on mathematical relations without limitations in avoiding regular geometrical shapes. In this paper "mutant screen" power is being shown that changes the original structure and transforms itself according to the quantity (covering) of the color. Mathematical screen is being defined through a screen cell and the space with unit cell. Hereafter is a screen named "grid – M" and its equation is:

$$M = \sqrt{|\sin(x^3) - \sin(y^7)|} \quad (1)$$

M = Sqrt[Abs[Sin[x^3] - Sin[y^7]]]

/M { 7 exp sin exch 3 exp sin sub abs sqrt } bind def

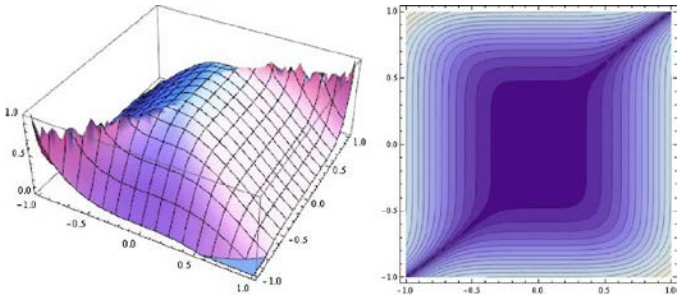

Fig. 1 Screen cell model and covering

Merging of two pictures for the visual V and near infrared spectrum Z is an extremely sensitive procedure that equalizes twin dyes with a different response in the visual and NIR spectrum.

Experimental works and applications have referred us to a simulation of colors with four process colors according to the design of new algorithms for each new dye combination, printing methods and material on which C, M, Y, K dyes are being applied. For example, the algorithm and the associated model as a set of regressive equations was published at the "Math…" conference in Venice in 2017. Dual information and dual printing on canvas with an HP plotter have been presented. We are aware of the fact that we still do not have a general solution where the same mathematical screening model would satisfy different printing techniques.

The problem is also in the experience of receiving the screen shape with our own eyes. Our experience of looking immediately recognizes straight lines, horizontal, vertical, diagonal, a circle, a parable. We are moving further from the existing printing practice that uses screen shapes with those primitive geometrical shapes. In the article we are suggesting a mathematical model (1) in Fig. 1.

A significant improvement in the process of hiding two pieces of information is being suggested through the use of screening shapes that do not have a regular geometrical shape and have at least two offshoot.

Mathematical models for pointed, skew, unsymmetrical, confused shapes are being introduced in the microstructure of printing screen elements. As opposed to the "Frequently modulated" models with tiny dotted elements, (albeit randomly dispersed) a "visible structure" of the screening element is being introduced but with an extremely branched description of a unit screen cell. Further in the article a screen structure through a relation named "grid - M" is being shown. The screen test display is at a 45 degree angle with 7 periods per centimeter.

The original code (PostScript) and a program for realization of such screen shape is:

```
/M { 7 exp sin exch 3 exp sin sub abs sqrt } bind def
7 45 {M} bind setscreen
10 830 translate 50 50 scale
4 3 4 [1 0 0 1 neg 0 0 ]
{<e1d4 935b ca76 >}
image
0.25 0.5 scale
0 7.5 neg translate
16 1 4 [1 0 0 1 0 0 ]
{<0123456789abcdef>}
image
showpage
```

This routine is being independently tested with a "GSview 5.0" program with a result in Fig. 2. The example has 12 four-bit pixels with a covering defined in a hexadecimal code: e1d4 935b ca76.

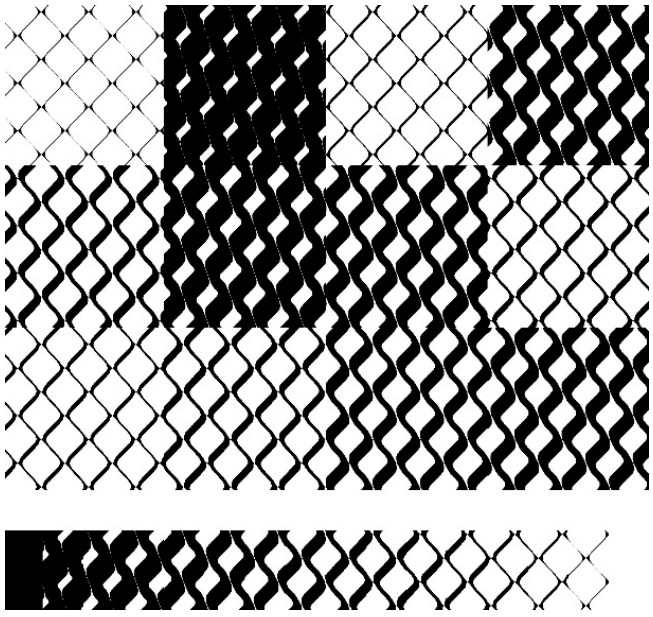

Fig. 2 Screening

Screen shape grid-M has inside holes. This detail gives good results for dying with twin dyes. For example: the cavity is dyed with a twin Z, a dye that is recognized by a NIR-Z camera. In reality it is impossible to maintain the print with the same color tone of twins, even though many experiments are being performed before a massive application of twin dyes. Branched screen shapes, such as screen M, improve mutual hiding of two identical color tones, but with different components (Table I).

Hereafter you can find screening of a portrait with the model "grid-M" and low period of raster lines. (In the expanded article the portraits of the authors are being hidden in a computer graphics and prepared for being presented in a real viewing at the AMACS conference).

Fig. 3 Portrait prepared for IRD print with a screen "grid-M"

## III. Needle Screening

"Grid-M" screening shape reduces the experience of recognizing a hidden picture. It has been applied only to carbon black dye. It has been applied on plotters DURST, HP, printer OKI543 with the same design. After a poll has been performed on around 10 students, their statement "we do not recognize, we do not decrypt" the hidden image with a naked eye" has been accepted.

Typographic symbols are being recognized the fastest in IRD technology. A regular letter symbol has sharp contours, mostly straight and regular rounded lines in order to improve the legibility of the text. For them we suggest "needle screening". "Needle design" of letters means that the letters are composed of small randomly distributed lines. The lines are dyed in carbon black color or with a Z twin dye. The edges of the letter are "torn", needle-shaped, jagged. The lines in letters leave small white clusters. These empty spots will be filled with a visual V twin dye of the same color tone as the color of Z twin that is used for coloring the letter body.


Fig. 4 Needle screen

Fig. 5 T-shirt on Jana in V and Z spectrum, animation at:
http://nada.ziljak.hr/haljina.mp4
http://nada.ziljak.hr/haljina.swf

For a conference 2019, the print was prepared on the black canvas that is "white" for a NIR-Z camera. Two black dyes (V and Z) have a different response in Z spectrum. The fabric has been dyed with black dyes that reflect the NIR wave length. A text in carbon black dye that absorbs NIR light has been added to such fabric [6]. The fabric and the text have been dyed with two black dyes so our eyes cannot read the text but the ZRGB camera recognizes the text (Fig. 5).

## IV. Simulation of Dyes in Fine Art

Every dye in fine art has a duality in the visual and near infrared spectrum. Painters use a huge number of color nuances without thinking about their response in the infrared spectrum. Dyes for graphic printing industry use only four colors that can achieve countless tones of other colors by using the technology of screening. We have developed a new graphic practice that performs a reproduction of paintings in two spectral areas. the idea is to introduce a new practice into a printing reproduction that also contains NIR dye characteristics that the artist used to work with. Infrared painting, as well as infrared production is a significant step in performing and proving the originality of the artwork. The restoration of the artwork has a new task. New studies about mixing dyes for two spectra are needed.

We have developed new ways of screening in order to truly reproduce the artwork with only four (C, M, Y, K) printing dyes in two spectra. Luckily, C, M, Y dyes do not absorb the NIR spectrum. The K dye is added through the method of VZ separation. The K dye, as carbon black, absorbs NIR-Z light.

The artwork that contain a dual image and its reproduction that also contains a dual image are being presented at the AMACS conference in real time. We are using a ZRGB mobile camera as a new tool in painting, in proving the authenticity of paintings and documents. A new area in visual art that includes topics from safety graphics and knowing the dye and color characteristics in two spectral areas is being opened.

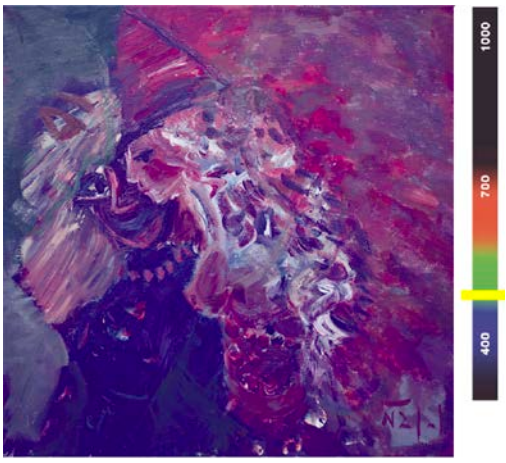


Fig. 6 The artwork in two spectra,animation at:
http://nada.ziljak.hr/n138.mp4
http://nada.ziljak.hr/n138.swf

## V. Conclusion

Expansion of the new model "grid-M" application is in coloring the other dyes in printing technology: cyan, magenta and yellow. In practice, a random lay-out of rotation angle of the screening element and line period of the screening element are being added.

With the mathematical model "grid-M", safety graphics gets a new direction in the research of generalization of the application of the given design for the performance of hidden information on different materials and in different printing techniques.

At the congress, live demonstration, a visual and Z picture are being demonstrated with a request to confirm the success of the mathematical model "grid-M" as a screening element in achieving the invisible picture and which is being taken out with a NIR-Z camera and projected with a video projector.

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