

DYE SPECTROSCOPY IN THE VISUAL AND NEAR INFRARED SPECTRUM

SPEKTROSKOPIJA BOJILA U VIZUALNOM I BLISKOM INFRACRVENOM SPEKTRU

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ABSTRACT

Electromagnetic spectra in the range from 400 to 1000 nanometers were examined using dual cameras with light filters in the visual and near-infrared (NIR) spectra. Near-infrared spectroscopy of dyes in fine art initiated the concept of "IR - Art". The painters mix the dyes depending on their property of absorbing and reflecting light in the infrared region. We assign each dye the value Z, which is the measure of the intensity of light absorption in the NIR (Z) spectrum at 1000 nm. We introduce the designation "VZ" that the painter manages: the appearance, hiding and separation of two images into visual (V) and NIR detection. With the NIR camera, the painter plans and creates Z graphics, Z images, Z typography.

Due to the appearance of VZ painting, we propose a change in the technology of restoration of works of fine art. The restorer will consider the colorant properties and their characteristics in the V spectrum as well as in the NIR spectrum. The new VZ painting was tested by artists with the intention of expanding their personal tools in hiding and showing intimacy. The Hidden Z image is also an extension of the technology of creating the security and originality of a work of art in a new way.

Keywords: NIR spectroscopy, Hidden image Z, NIR painting, Art and science in V & NIR, INFRAREDESIGN®

SAŽETAK

Ispitivani su elektromagnetski spektri u području od 400 do 1000 nanometara pomoću dvostrukih kamera sa svjetlosnim filterima u vizualnom i bliskom infracrvenom (NIR) spektru. Bliska infracrvena spektroskopija bojila u likovnoj umjetnosti, inicirala je koncept "IR - Art"-a. Slikari miješaju bojila, ovisno o njihovom svojstvu apsorpcije i refleksije svjetlost u infracrvenom području. Svakom bojilu pridružujemo vrijednost Z koja je mjera intenziteta apsorpcije svjetla u NIR (Z) spektru na 1000 nm. Uvodim oznaku „VZ“ s kojom slikar upravlja: pojavljivnje, skrivanje, razdvajanje dvije slike na vizualno (V) i NIR detektiranje. Pomoću NIR kamere slikar planira i stvara Z grafike, Z slike, Z tipografiju.

Zbog pojave VZ slikarstva, predlažemo promjenu tehnologije restauriranja likovnih djela. Restaurator će uzeti u obzir svojstva bojila i njihove karakteristike u V spektru, kao i u NIR spektru. Novo VZ slikarstvo testirali su umjetnici s namjerom da prošire svoj osobni alat u skrivanju, pokazivanju intime. Skrivena Z slika je ujedno proširenje tehnologije stvaranja sigurnosti i originalnosti umjetničkog djela, na nov način.

Gljučne riječi: NIR spektroskopija, Skrivena slika Z, NIR slikarstvo, Umjetnost i znanost V & NIR, INFRAREDESIGN®

1. INTRODUCTION

1. UVOD

The art works of the old masters housed in museums and art galleries are often imaged using visible and NIR light in order to authenticate the provenance of the artwork [1]. With infrared reflectography (IRR), a large collection of photographs of works of art was made, presenting them in two spectra with a visual and NIR spectral record. It is a good basis for discussing the proof of originality of a work. However, image restoration did not consider image repair in the NIR spectrum as well. The question is: "What determines the original?" Especially in the present day of the new IR Art painting, when there are two paintings on the canvas: two independent images, one created for our naked eye and the other for the NIR spectrum.

Infrared dyes are applied to documents, such as banknotes. The author of our notes, Dr. Vilko Žiljak (kuna, Croatia), points out that two spot colors (V and Z) are designed, printed side by side.

It is only with later development that a group of professors from the University of Zagreb developed two nested graphics, so that the hidden Z graphic cannot be identified with our naked eye (Croatian National Bank).

The topic of this article is the creation of dual paintings (two individual paintings on the same canvas) which were investigated with VIS and NIR forensic cameras [2]. The light absorption characteristics of colorants (i.e. dyes and pigments) used in fine arts (Figure 1) have been shown to have unique visible and NIR spectra (Figure 2). Some colorants absorb NIR intensively, while others reflect NIR wavelengths which can be seen in the corresponding NIR image (Figure 1b). An example of extreme light absorption change is the application of colored glazes on ceramics, which mature during the high temperature firing process [3]. This article is focused on colorants for painting on canvas [4]. The difference of these absorbance values has initiated the new painting approach called "Infrared Painting" [5].



Figure 1 a) Tempera colorants for fine art paintings; b) NIR image of tempera colorants for measurement of Z value at 1000 nm

A large collection of new art is on display in galleries and museums [6]. For example, in security print, different structures of the same color have been achieved by mixing different colorants with a specific aim of placing hidden graphics in two spectral regions [7]. The hidden image can be visualized by use of an NIR camera. Color can be achieved in several ways, with different components, and their spectrograms are differentiated in the NIR region. An example is the color black, used in the printing industry, which can be prepared using two methods. The first black „S-type“ reflects NIR, while the other, carbon black, (Table 1, No 1) strongly absorbs NIR radiation [8]. S-type black is a mixture of the printing process inks cyan, magenta and yellow [9]. A new visual - V and NIR - Z graphic technology called "VZ" has been developed and successfully implemented in security graphics [10]. The security design has been proposed in a new way in designing a typical graphic vignette as a line graphic in dual V and Z in the spectral region [11]. The complex tasks of hiding graphics have expanded the field of mathematical modeling in printing rasterization (screening) [12].

The packaging industry has embraced new NIR VZ graphics that carry hidden, secure information [13]. The duality of colorants in NIR light absorption can also be achieved for many other color tints with extremely different structures. The colorants for the textile printing industry, the design of the document protection and information technology have been studied in our graphic art laboratory for printing practice [14]. INFRAREDESIGN® motivated artists from the theater and film industries. Costume design was developed with a new dual stage design [15].

The determination of the dual designated color and colorant structures is based on the spectrography of the colorant for the fine art which includes the visible (V) and near infrared area [16] (Figure 1).

2. INSTRUMENTS AND MATERIALS

2. INSTRUMENTI I MATERIJALI

This article presents the results of measuring light absorption in the V and Z spectra. Spectral imaging was performed using systems: Projektina with 24 filters [2] and ZRGB cameras [17].

Table 1. Measured absorption values of various Color'peps Gouache Poster Paint Temperra (MAPED, Prod210317B, 12 x 12 ml)

| colorant / dye | λ max (nm) | Absorbance (at max.) | Absorbance (at 900 nm) | Z (% gray (at 1000 nm), Figure 1b. | L*a*b (CIE coordinates) | RGB |
|--------------------------|--------------------|----------------------|------------------------|------------------------------------|-------------------------|-------------|
| 1 – BLACK, 563.1 | 727 | 0.886 | 0.203 | 91 | 12, 0, 0 | 32, 32, 32 |
| 2 – BROWN, 563.7 | 556 748 | 0.461 0.446 | 0.171 | 61 | 25, 31, 24 | 106, 36, 25 |
| 3 – green EMERALD, 498.7 | 717 | 0.907 | 0.143 | 67 | 37, -26, -3 | 8, 98, 90 |
| 4 – CARMINE, 498.3 | 556 | 0.518 | 0.091 | 28 | 40, 56, 40 | 177, 33, 31 |
| 5 – MARINE, 563.4 | 717 | 0.848 | 0.068 | 40 | 21, 16, -44 | 31, 44, 116 |
| 6 – green KIWI, 498.6 | 479 724 | 0.340 0.793 | 0.127 | 55 | 49, -46, 35 | 11, 135, 52 |
| 7- ORANGE, 461.9 | 529 | 0.452 | 0.066 | 25 | 51, 55, 55 | 211, 70, 25 |
| 8- PURPLE , 563.2 | 643 | 0.550 | 0.074 | 36 | 24, 24, -45 | 59, 46, 128 |
| 9- YELLOW, 461.6 | 480 | 0.338 | 0.040 | 29 | 76, 5, 77 | 222, 183, 2 |
| 10- MAGENTA, 498.2 | 557 | 0.501 | 0.095 | 33 | 40, 53, 23 | 172, 42, 60 |
| 11- CYAN, 563.6 | 718 | 0.884 | 0.110 | 47 | 35, 12, -60 | 0, 81, 181 |

Various colorants were studied: acrylic, oil paints, watercolor paints, pastels and ceramics. This article presents the numerical values for tempera dyes (Table 1,) as well as the associated spectrograms. Tempera colorants (Table 1) were sourced from MAPED (Argonay, France).

The gray value of absorption – “Z” is measured by the Z-camera with a filter at 1000 nm (Figure 1b, Table 1, column 5). “Z” value is necessary for the painter in order to use the dye for creating a hidden multi-dimensional image. The colorants No. 4, 7, 9, 10 have low absorbance values above 700 nm. Such colorants are called „V colorants“. Colorants with absorption in the NIR spectrum (Table 1, No. 1) that have absorbance values greater than 0.2 are called “Z colorants”. Such values are recorded by NIR cameras with almost 100% of dark - gray to carbon black coverage. Mixing colorants No. 9, 10, and 11 manifests as an "S" colorant (black tone) such as the one used in printing technology. Furthermore, the painter uses the NIR camera and the parallel NIR projection in the creation of new paintings. Parallel consultation and observation of V and Z values according to V and Z photographs (Figures 2a, b) opens an unlimited number of combinations of new colorants with the default, desired absorption values for the NIR - Z camera. The new painting style has been named “NIR painting”.

3. DEVELOPMENT OF V-NIR PAINTING

3. IZRADA V-NIR SLIKA

Art works have been observed in near infrared light based on colorants which are differentiated according to their NIR absorption in the range from 800 to 1000 nm. The painter Nada Žiljak has adopted the idea of color duality and hides her graphics from the naked eye. These innovative dual paintings are works of art that are observed in parallel using visible and NIR light. To create and view the images two cameras are required.

One camera is tuned to record the image in the visible daylight spectrum, and the other is tuned to record the image in the NIR region.

Every new color has been achieved by mixing several other colorants. Spectroscopy directs us towards the improvement of the colorant structure i.e., the modification of the quantity of colorant components. The aim is to achieve a colorant which has a determined value of light absorption in two different spectral ranges. The specific challenge is to achieve two colorants which are identical in color (visible spectrum region) but different in the light absorption value in NIR spectrum region.

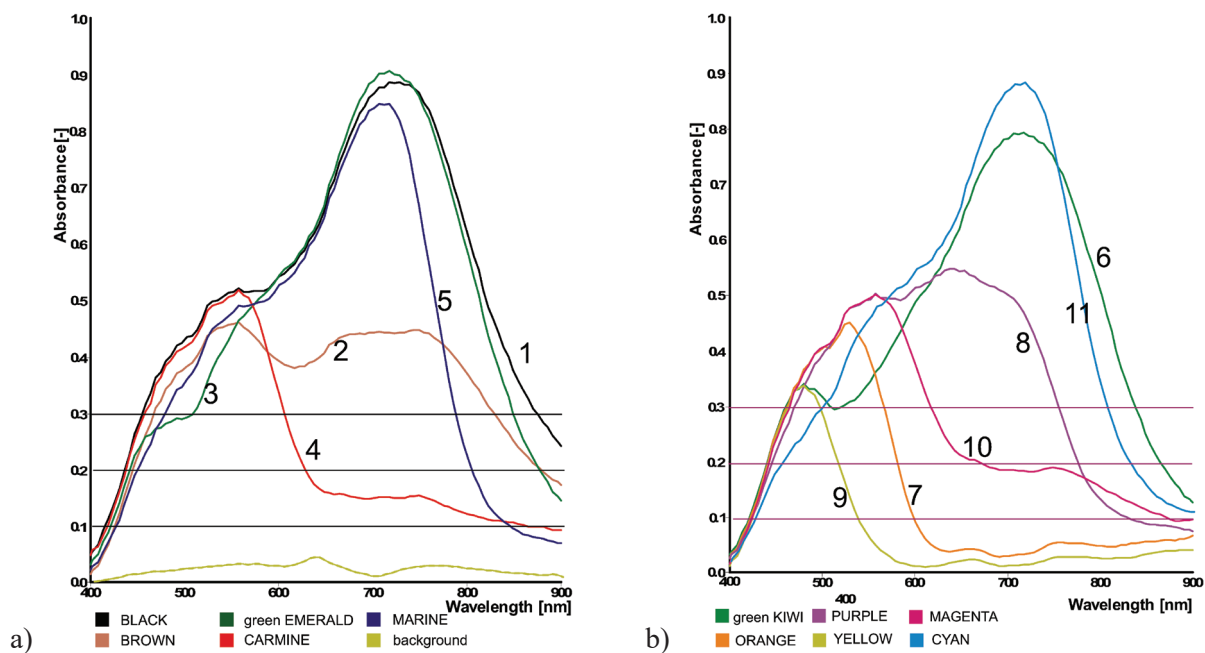


Figure 2 a) Spectrograms of tempera colorants for fine art painting; b) Spectrograms 6 to 11



Figure 3 a) Dual observation and recording by RGB and NIR cameras; b) NIR record in gallery Zelina, VZ animation:
<http://www.nada.ziljak.hr/n108.mp4>

NIR spectroscopy opens up the possibility of a new procedure in fine arts for restoration and protection of art works. The colorants have different characteristics which are independent of the NIR light absorption that do not depend on color tints or their lightness in the visible spectrum. Their difference is the basis of the creation of the invisible multicolor painting, which is singled out by the NIR camera, separately from the visible painting. Two paintings are created on the same canvas and each of them is recognized by its own camera. The paintings in the two spectral ranges, visible and near infrared, are exhibited in the Art Gallery, town of Zelina, Croatia (Figure 3). The NIR camera has been adjusted to 1000 nm for the dual painting observation [2].

4. NEAR INFRARED SPECTRUM IN FINE ART PAINTING

4. *BLISKI INFRARED SPEKTAR U UMJETNIČKOM SLIKARSTVU*

The characteristics of Z-dyes suggest that the multicolored images painted by the masters throughout history have some sort of NIR graphics. The new V-NIR painting uses spectroscopy with the aim to create colors which will produce differences in the NIR region above 800 nm.

Today's collection of paint colors does not carry the information of their appearance in the NIR region.

The recording of V - NIR painting is created with the aim of dual content and it is not a simple passive observation - detection or passive recording in the V and NIR spectral regions. It expands the limits of painting into new innovative fields, and serves the creation of new art with the following characteristics:

- hidden graphics,
- image with security elements and
- non-replicable images.

More in-depth and detailed knowledge and analysis of the colorants in the NIR and V spectra are based on spectroscopy. The artists exploit an understanding of science and use a scientific display of colorants to produce novel art works.

Research with NIR spectroscopy is moving towards restoration of artworks with a new cognition of a numerical description of colorants out of the range of the naked eye. This new scientific field will arise as the basis of the art painting restoration. Restoration of art works uses many colors to bring them closer to the original structure and creation of the painting. The NIR spectrum consultation is here to stay since there are more and more owners of pictures / artworks and paintings of fine art who own an NIR cameras.

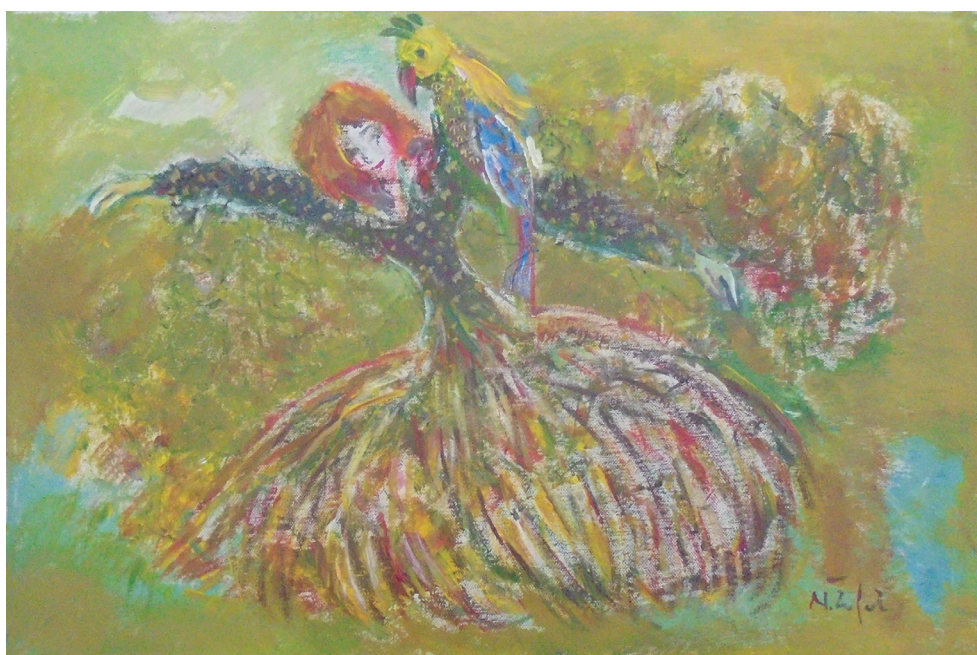
The study of the numerical descriptions of colorants has initiated the extended practice in painting, design, computer graphics and fine art artistic imaging.

Spectroscopy is the way to achieve success in the given difference of NIR light absorption of two colorants which have the same color tone, in short - the same color in the visible spectrum.

Spectroscopy is implemented for all “raw colors” from the fine art shop. Those colors can be used by painters as components in creating new colorants with desired qualities of light absorption in the visible and NIR spectra. Two images (V and Z images) exist in all paintings of old and contemporary masters and each color has its own characteristics of NIR light absorption.



Figure 5 Animation in visible and NIR spectrum, <http://www.nada.ziljak.hr/n136.mp4>, exhibition catalogue: <http://nada.ziljak.hr/Katalog-Mimara-2018.pdf>



a)

Figure 4
a) New fine art in visible spectrum;
b) New fine art in NIR spectrum



b)

5. THE PAINTING WITH NIR CHARACTERISTICS OF COLORANTS

5. *SLIKARSTVO S NIR KARAKTERISTIKAMA BOJILA*

The artist can use the V - Z scientific knowledge for the purpose of a new approach to painting. This is an undefined stain, the uncontrollable NIR image without any meaning if observed as an isolated old master's work of fine art. The other image, the image with a meaning and possibility of joining of the painting's content of the V and NIR image, is in the new NIR art procedure. The painter can recognize the characteristics of each color in the NIR spectrum, and they can achieve a dual image with a controlled outcome. This can lead to a new image signature based on the separated V and Z images which are selected according to the cameras used for recording.

As a final conclusion, NIR spectroscopy has shown that the colorants of identical colors in the visible spectrum can have different absorption values in the NIR region, depending on the origin of formation. For example, the spectra of two green colors (Table 1, No. 6 and 3) have similar tone (but different structure) are discerned by differences in absorption at ca. 480 nm (blue) and in the NIR spectrum. The NIR camera "sees" one green colorant but not the other. V and NIR colorants, equivalent in our eye and from the same manufacturer, present very different profiles of light absorption in the NIR region. NIR spectroscopy is information, a guide mark which enables the painter to create an isolated hidden image.

The new procedures in colorant mixing have been developed by creating colorants which have different absorption values in the NIR spectrum and equal colors in the visible spectrum. This enables us to paint the surface of a canvas monochrome, while the NIR camera will separate images with a different response in the NIR spectrum. Consequently, a new group of colorants has been developed. They are different in color in the visible spectrum, but they show equal spectrograms in the NIR spectrum. As such, the spectroscopy of colorants in the NIR spectrum has introduced us to dual painting.

Artworks can be observed not only in the visible color spectrum, but also in the NIR spectrum. The condition is that NIR spectra are different for different colorants. There is no correlation between the lightness of colorant in V and the absorption in NIR spectrum. That has led us to create the new "NIR painting", whose recent results are exhibited in Mimara Museum in Zagreb (Croatia), (Figure 4c) and in the Art Gallery, town of Zelina. NIR cameras are installed in the gallery in order to enable the visitor to uncover hidden information, hidden images, all of which is a new "Intention of V-NIR Artistic Expression".

The new procedures based on colorant NIR spectroscopy are offered to secure and confirm the originality of fine artwork. The innovation is significant for the painter, the gallery owner, the painting observer, the buyer, as well as the collector.

Hiding, the invisible image, intentional painting of an NIR image with a meaning, and the independent NIR image not visible by naked eye are just the beginning of the project involving NIR painting with different colorant groups: tempera, acrylic, oil paints, pastels, ceramic colorants and on materials such as canvas, silk or leather.

Artists are coming closer to the field of science by using scientific display of the colorants. Restoration will use new knowledge and numeric description of colorants in the spectrum outside of the range of the naked eye. The new scientific field will appear as a basis for the procedures in the restoration of fine art works in painting, design, computer graphics in fine art and artistic imaging.

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