Simulation the colors from nature with twins dyes to camouflage military uniform

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INFRAREDESIGN is based on the idea of merging graphics of two colour groups with the same color tone; the dyes V (visual) and dyes Z (near infrared). The concept of twins is introduced through the same color in the visual spectrum in the system of filling the RGB color (red, green, blue). The twin dyes absorb a wavelength of infrared light differently. The twin dyes differ only by the value of the absorption of the NIR light at 1000nm. By simulating nature colors to camouflage military clothes, the goal is successfully reached; the integration of soldiers into a natural environment, which is surrounded by two spectral regions: visual and infrared. The infrared dye carries hidden information that is revealed under planned conditions. The procedure of INFRAREDESIGN technology allows a soldier to covert acts on the battlefield and perform a given mission undetected. The IRD Information is invisible to the naked eye. The Z - IR camera has a double purpose: to discover a hidden picture and make it possible to read the information.
***Key words**: military uniforms, INFRAREDESIGN, individually rasterization, spectrum of twin dyes*

1. Introduction

Mathematical models and basis of reproductive graphics technologies are based on the CMYKIR separation of dyes [4]. The first test colors were used from nature in order to achieve camouflage systems with double-information that are separated in the visual and infrared spectrum [5]. Signs or text, visible in the infrared part of the spectrum located on a piece of cloth in a specific time then add-pasted on the uniform (using the "thistle"). As a result, it can serve military surveyors or raiders when returning from enemy territory, when moving the positions of their troops, as the "friendly" soldier. Thereby, fratricide can be avoided (opening fire on friendly troops replaced by the opponent). There are a lot of types of information that can be "hidden" in a military uniform in a selectable infrared part of the spectrum. Information about the soldiers' blood group who wear such uniform, is coded for identification purposes only for cameras with an accompanying program. This information can be critical for medical service if the soldier is wounded and unconscious.

Flora and fauna have their own color, absorption of ultraviolet and infrared sunlight. Former camouflage clothing is dealt only by identifying visual dyes and nature. The intention is to expand the knowledge of the absorption and reflection of light to create a new "color / colorant management" [2]. The theoretical basis INFRAREDESIGNR [6] becomes applicable for military purposes in the area of camouflage uniforms and equipment. Fellowship feeling of colors and material properties of dyes is introduced in the information system, in order to equalize the color space which refers to color space that come from nature. The ZRGB camera system consists of two cameras when connected they both focus on the same object. The first Z camera filters only near-infrared light in the value of Z at 1000 nm. The second V (RGB) camera only records in the visual range 400 -700 nm. A slipstream 700-850 nm does not enter in the V and Z cameras because there is mixed visual remnants in that of the spectrum and light starts near infrared light.

The simulation with process colors has been developed in several steps [4], which depends on the material that should be incorporated in the V and Z graphics. Military uniforms are very challenging to set twins as they combine two disparate technologies [5]: Making canvases with properties of dyes for computer inkjet printing while still maintaining colors that are washed and suffer other atmospheric effects. Our research involves the problem of contact twin dyes through individual rasterization. Each dye component joins a special screening element [7]. The first in camouflage clothing, INFRARED treated in relation to the environment from nature and printing, coloring cloth [8]. The disadvantages of such research is identified and detected as collision twin dyes. This opens up a new way to explore the properties of the components of dyes through spectral scanning procedures of prints [9, 10]. This paper illustrates printing (coloring) the military camouflage clothing using the properties of dye in the visual and infrared spectrum. A sign, text, or code is entered in military clothes, colored (printing) with dyes that are not visible to the naked eye. A Z mark [1] is conceived and the realized clothes are recognized by infrared camera, which skips the visual spectrum. Dyes are based on the theory of twin color [2] having the same color tone and different material compositions depending on the properties of absorption of infrared light, Fig.1. The ZRGB dual cameras [3] are used in the IRD technology in order to simultaneously determine the visual and infrared information on the uniform, as well as the difference and correlation of information on military camouflage. The ZRGB camera allows a digital recording double-V and Z graphics that are located in the same place but separately manifested, each in its spectrum.

2. Methodology of work with discussions

The aim is to make V-camouflage while Z hides information. The colors of nature are bright, dark, bright colored flowers as depicted in Fig.2; yellow, purple and red. Camouflage clothing uses several tones in larger areas. All color shades and dyes from nature are subject to spectral analysis.

2.1. Hiding the information in the visual spectrum

There are two degrees of hiding as seen in Fig.1. The first is the surrounding of nature and of color that simulates the environment. The second stage is to hide the information within a relationship of two dyes, two colorant twins. The uniform color is carried out with digital techniques in process dyes: Cyan, Magenta, Y-yellow and K-black. The tone colors from nature are simulated with two dyes in the same tone as the surrounding. The first dye is only intended for simulating the nature with dual identification in the visual spectrum. This dye does not absorb IR light. The second dye has the same properties in the visual spectrum, but in the infrared spectrum it is shown "seen" as Z value, which holds hidden information. Hidden from our eyes. These two dyes make the ZRGB camera different as these two dyes differ in the structure composed of CMYK components.

The aim of flora spectrum is to make twins with conventional and digital techniques in coloring textile and leather [8, 11]. This simulates nature with dyes from the digital plotter. Simulation means performing the twin colors in nature equality. Dyes for printing are defined through CMYK components for digital plotter. Hiding inside the twins is successful only if V and Z twins are equal in V shape. The quality of twin colors and dyes is a compromise that is defined as the size of the ΔE (color difference). The satisfaction of this criterion is that the ΔE size is up to three. Maintaining these values depends on the stability of selected dyes and their relation to the invasive action of humidity and outdoor light. The aim is to improve the reduction of the visual differences of the twin dyes with the introduction of "divorced raster screen form."

Fig.1 Desert uniform and leather belt with hidden information

2.2. The spectrum of flora in nature

Nature may have a color with a significant Z value. These are carriers of the hidden information dyes, which have a value equal to zero Z. The spectrum of dyes from nature determines the decision of which twin dyes will extract hidden information. Flora and fauna have their own colors, absorption properties of ultraviolet and infrared sun radiation. The color of skin, hair, blood and flesh from the world of fauna are a separate task performance with a tendency to hide information from our eyes. Fauna encompasses a very extensive range in the infrared region, which requires a different approach to color matching, when viewed in the surrounding flora. The IRD procedure is equal to flora and fauna but the choice of dyes must be determined by the environment where the soldier moves. In the same manner, but with different IRD solutions, the soldiers' movement was studied in a sandy environment, woodland, town urban environment and in a rocky area.

Fig.3 depicts the spectrum obtained by scanning the flora. After 1000 nm there is no longer isolated information that would enable the classification of flora according to the properties of light absorption of these wavelengths. Method [6] INFRAREDESIGN sets the simulation of these tones to the printing techniques, which identifies the color in the visual spectrum before 700 nm and spectra the flora after 700 nm.

2.3. Simulation colors of nature with twin dyes and individualized screening

The screening is performed with the PostScript method that enables the creation of individualized "personal raster form" [7]. The choice of model grid is such that it creates a visual "vibrating effect" on the contact points of two different dyes with equivalent color tone. The disruption in the continuity of mutual crossing surfaces of the same color, but different composition, is also a new way of solving moiré.

The input data of CMYK digital procedure for filling raster cells are: the value of the coverage area to be screened and the coordinates x, y within the raster cells with domains from -1 to +1. This paper presents the original relation with mutation modification of the circuit and a ring, as published in the book J. Žiljak Vujić "Security Graphics" [7]. The military uniform has been colored with digital print on canvas. [8]. Digital printing on canvas of twins is performed with the technique of a screening process with dyes [9]. It presents two tones in two sets of twins: a gray tone (Fig.4) and an olive tone (Fig.5). Fig.4 and 5 shows the same color twins that the screen elements cannot be seen with a naked eye (60 lpc) and also twins with a rough line screens from just one screen element in the centimeter. Only high line screens results in an experience of two equal toned twins. Twin dyes are presented in two ways: in a low line screen from one line per centimeter. At a first glance, there is an impression that these twins do not produce the same color tone. Only when the twins are observed in high resolution, at 60 lines per centimeter, the same color tone is perceived. Low line screens check the quality of individualized raster form. Cyan is joined to a circular shape, magenta to a ring, yellow to a triangular shape. A square shaped screen element is joined to black dye. This is an addition to our protection system in infrared graphics. The right twin responding to Z spectrum. The left twin has no positive Z value and the infrared camera cannot see it. The left and right are identical twin tones for spectroscopic instruments and for our eyes only when the resolution rises above 40 lines per centimeter.

Twin color tones in Fig.4 and 5 have equal value of coverage. The left gray twin (Fig.4) is composed only of C,

Fig.2 Flora in the visual (left) and infrared ZRGB recording (right)

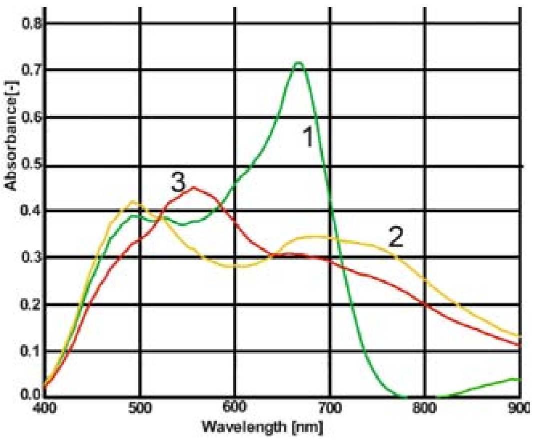


Fig.3 Spectral characteristics: 1 - green leaf clover, 2 - dandelion and 3 - clover flower

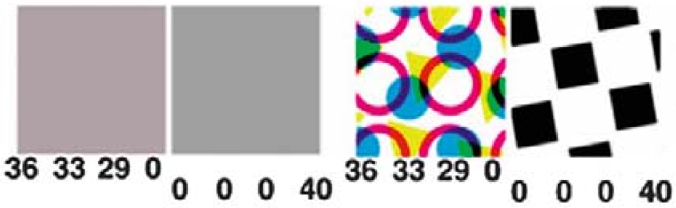


Fig.4. Gray tone of twins in high (60 lpc) and low (1 lpc) line screens

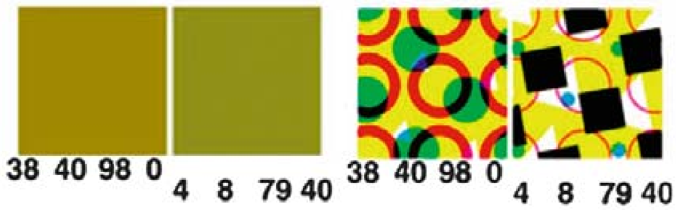


Fig.5 Olive twins in high (60 lpc) and low (1 lpc) line screens

M and Y colorants (36%, 33%, 29%, K = 0). Tagged values for the right gray twin which appears in the infrared spectrum are: C = 0%, M = 0,%, Y = 0%, K = 40% coverage. Olive twin (Fig.5) has the coverage value for C, M and Y colorants: 38%, 40%, 98%, K = 0), and the right olive twin in Fig.5 has a coverage value of C, M, Y, K = (4%, 4 ,%, 79%, 40%).

The individual shape of the screen element is applied as a secondary part of the security camouflage system. IRD technology is based on the total identity of twin color and is almost impossible to achieve. The colors change differently over time, depending on the composition of components that make up the color. Several processes have been developed which consist of the introduction of an individual grid and change the half toning angle with pseudo random congruence methods. In reality, the camouflage uniforms add to the diversity line screens of the channel colors. Recognizing the raster concept is harder for a ring shaped screen than for dotted shaped screens. Thereby, "picking one screen element in the second" in a "discontinuous mode" is achieved and reduces the level of competence in our eyes in an eventual error of twin colors. Mathematical expressions (1), (2) and (3) of the individual raster form and their PostScript performance for digital printing form are given in Fig.6-9.

2.4. Models of raster shapes for INFRAREDESIGN print

Models of raster shapes for INFRAREDDESIGN print are given in mathematical expressions (1), (2) and (3) of the individual raster form and their PostScript performance for digital printing form are given in Fig.6- 9

The circular shape is defined as a cone opacity "jr1":

$$\sqrt{x^2+y^2} \tag{1}$$

as in PostScript writes:

```
/r1 {dup mul exch dup mul
add 1 exch sub} bind def
```

Filling the raster cells is carried out to the point it reaches default coverage

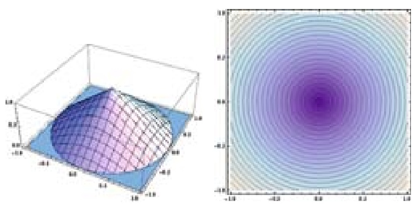


Fig.6 The cell circular grid in 3D and 2D filling the coverage

The ring grid without concentric circles j „JZVr20":

$$\text{Abs}\left[\text{Sin}(2\sqrt{30}\sqrt{x^2+y^2})0093\right] \tag{2}$$

as in PostScript writes:

```
/JZVr20 { dup mul exch dup
mul add sqrt 120 mul sin
abs} bind def
```

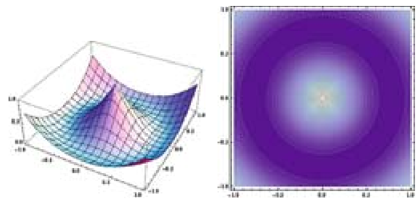


Fig.7 The cell ring grid in 3D and 2D filling the coverage

Square, "kare" form „r4":

$$1- ½ \text{ Abs } (\text{Abs } (x) + \text{Abs } (y)) \tag{3}$$

as in PostScript writes:

```
/r4 {abs exch abs add 2 div
1 exch sub} bind def
```

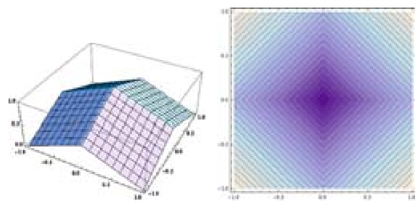


Fig.8 The cell of a square raster to 3D and 2D filling the coverage

The triangular shape:

For unit area definition of raster cells: x (-1 to 1) and y (-1 to 1) is set the relation:

$$\frac{2* Abs(y) - x}{3} \tag{4}$$

as in PostScript writes:

```
/trokut {neg exch abs 2 mul
neg add 2 add 3 div} bind
def
```

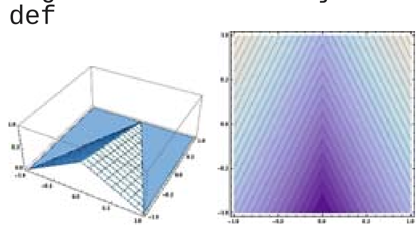


Fig.9 The cell triangular raster to 3D and 2D filling the coverage

There is database of the individual grid, for any occasion with other combinations. Divorced, asymmetrical rasters, trigonometric rasters and mutable forms. They all increase the rhythm in our eyes; increase the "dot gain". Such raster shape programming improves the invisibility narrowing and contact of V and Z information. The boundaries between twins of the same tone become "visually softer" and increase the invisibility of V and Z information in the visual spectrum.

2.5. The spectrum of twin dyes

The individual dyes in the twin IRD system have a specific domain. Fig.10 presents the information reading from their spectra [8]. The spectrum of 400-1000 nm is divided into three sections: visual, transient Z_1 and Z_2 camouflage. The paper presents two dyes: brown and green. Simulation of these colors is performed in a digital printing process with dyes of a value share (in%) are given in Tab.1. These sizes are incurred after six iteration settings equality of colors in the visual spectrum. Both dyes have the same value of carbon black components: 40% for the coverage of Z dyes and 0% for V dyes.

Tab.1 Share of C, M, Y, K (%) in the process dye-twins

	Visible twin C,M,Y,K	Hidden messages C,M,Y,K
green	85, 32, 94, 0	70, 0, 74, 40
brown	48, 62, 90, 0	0, 58, 80, 40

Both dyes have similar values as yellow components. This is the reason why all four graphs overlap in the spectrum 400-500 nm, spectrum that gives information about the yellow tone digital printing.
The green color is shown on the chart in green (V twin) and black (Z twin). Brown color is shown on the chart in red (V twin) and dark brown color (Z twin) [9]. For each pair of twins the goal was to agree with V and Z of colors in the visual spectrum. The two dyes will give the same sense of color to the naked human eye. If the two graphics (with different dyes and similar color) are printed alongside each other, our eyes will not differentiate them. They will not vary neither will the RGB camera system from ZRGB camera. A brown and a green color tone is achieved by a numerical value ΔE less than 2 (ΔE brown = 1.88; ΔE green = 1.70). These values measure the similarity of colors only in the visual spectrum, which is given

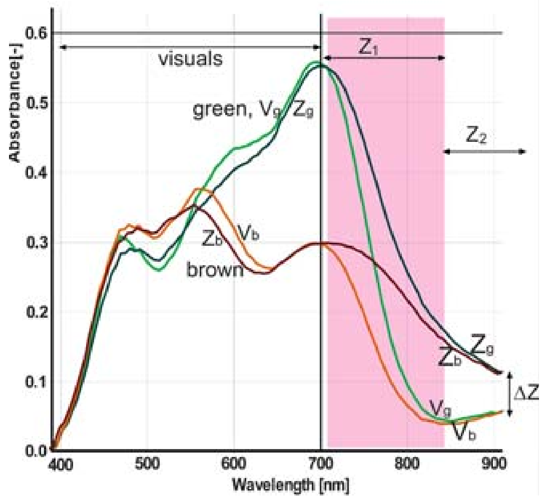
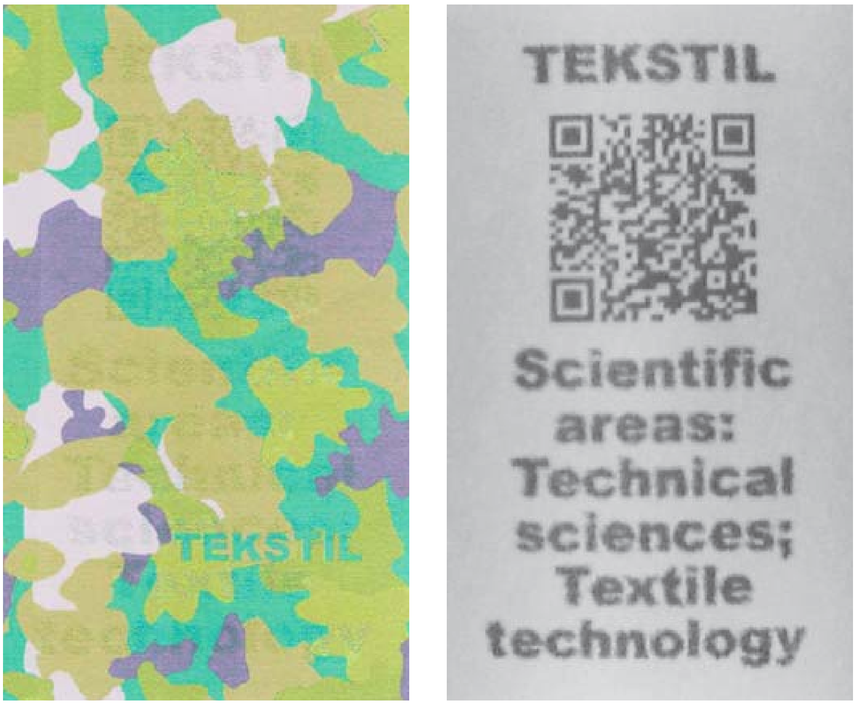


Fig.10 Four colorants: green V_g, Z_g, and brown twin: V_b, Z_b

in the theory of "color management". INFRAREDESIGN expands the color management in the near infrared spectrum, which would then have two sizes ΔE and ΔZ. The aim is to introduce new graphical features as "information hiding", "security graphics", "double vision" [2].
The separation curve of the same color tones give to the ZRGB camera the possibility of distinguishing dyes in the near infrared spectrum indicated as the ΔZ. Size ΔZ is the difference in absorption of light in the color dye in the infrared spectrum. The difference of 0.1 ΔZ absorption, is enough for ZRGB cameras to have different prints made with these dyes. The separation curve of the same color tone provides the ZRGB camera with a possibility of distinguishing dyes in the near infrared spectrum indicated as the ΔZ. Size ΔZ is the difference of light absorption in the dye color in the infrared spectrum. The difference of 0.1 ΔZ absorption, is enough so that the ZRGB cameras make different prints with these dyes. Brown and green dyes have the same value in Z2 at the end of the spectrum. This will allow for the text on military uniforms to be in equivalent intensity for all characters when viewed with an infrared camera. This applies to all colors on uniforms as shown in Figure 11. All the spectra of V dyes are joined at the same point, which is the lower value of the point where Z dye graphs are connected.
The area 700-850 nm we called "transitional Z1 spectrum" since it results in the separation of spectral values of twin dyes. Two dyes are deliberately displayed in the same chart. Mixing V and Z graph illustrates why the filter Z camera shifted to 1000 nm. In the transition area Z1 is mixed information coming from the twins. Each color has its own way in the continued progress towards a steady state of

Fig.11 The greenish uniform in visual sight and in IR shooting with Z information



a) b)

Fig.12 Camouflage design in a) visual spectrum and b) in spectrum Z 1000 nm

Fig.13 The mask design with a blockade on a) 570 nm, and b) 715 nm

absorption of infrared light above 850 nm.
The first stage of the INFRAREDESIGN implies clothing identification with the environment in the visual and infrared spectrum. If necessary, it may be the prevalence of green, blue, black or certain default colors. Uniforms are designed in accordance with the intended use. In nature, the flora is green camouflage clothing and does not discern the infrared camera if colors and shapes on clothes are similar to the environment. Uniforms that are used in urban areas are subject to different requirements.

2.6. Information hidden from the naked eye

Hidden information - Z graphics can be a text, drawing or a special character. The procedure for intergrading information in the IR spectrum through QR code additionally hides the text information and this is the reason why mobile IR camera with software for reading IR code is created.
The print on canvas shown in Fig. 12 contains a Z image that is hidden from our eyes. Z camera sees a hidden image, text and QR code (Fig. 12b). Color twins are arranged so that the naked eye cannot see information that is embedded in all of the process C, M, Y, K channels. The CMYKIR separation method merges the two images in a way that the initial V picture remains the same to our eyes in the visual spectrum. (Original print on canvas is added to the printed version.)
Marking the mask design as the hidden text information has the form: “TEXTILE Scientific areas: Technical sciences; Textile technology “(Fig.12) and the information in the QR bar- code that provides data:” Textiles, a magazine for the textile and clothing technology “. This QR barcode information can be read in article (Fig.12b) with various programs such as: i-nigma, with a mobile phone.
The realization of textual information is solved by the graphics decorated in an alternating rhythm with the “needle” model of breaking the edges of the letters. Interruptions in the graphics on “dark / bright cuts” staged as “serrated typography” is a significant contribution to the of IRD technology of hiding the object, which in general is known. As letters, for example.
The mask design (Fig.13) is scanned from the filters in blocked shots at 570, 715 nm. In the first Fig.13a) yel-

low component is filtered, the second Fig.13b) shows the camouflage design without magenta and the yellow [10], [11]. This is a transitional Z_1 spectrum where residual forms are shown, intended for the visual spectrum. The Fig.12b is equal to the input Z image that exists in the material that carries the Fig.12a. This is space Z_2 spectrum where there is no information from the image intended for the visual spectrum.

As soon as a filter is used, there is a "springing" text and code information since it disturbs the harmony process of the twin dye method CMYKIR [4], with which the print on canvas is performed. The question remains: how to make commercial filters for a specific wavelength domain for example, "only cyan filter" or "filter out only the magenta?" from the print on canvas. For this purpose, forensic instrument PROJEKTINOVA 4500 [12] at the position of 1000 nm was used and the ZRGB camera produced by FotoSoft [3].

Using the "twin method" allowed the display of hidden information on military uniform that can be encoded or as the generally known character or text visible in the infrared part of the spectrum. Thus, the information presented may serve military **scout** or **commandos** when returning from a hostile area to be recognized as a "friendly" soldier and the avoid "friendly fire (fratricide)". The use of "twin" color simulation from nature allows camouflaging military clothing. This allows a soldier in action in the area to acquire tactical advantage over the opponent as he is disguised in a time when it is needed. At the same time visible and recognizable by his troops when there is a chance to die from friendly fire.

3. Conclusion

Marking military uniforms is carried out with double dyes: for visual and infrared spectrum. Dyes simulate the colors of nature and environment in which there is a soldier. The hidden information is merged in the camouflage design with a method of divorced individualized raster. There are two advantages of such printing on military textile. Firstly, the level of micro-structure of printing in the application of dyes on cloth. Secondly, the improvement of "visually connecting" two different dyes of the same color tone using the properties of perception, that the naked eye cannot see well vibrant compound colors of equal tone. Camouflage of the IRD system uses two sizes of theory "extended color management". These are differences of similarity of two dyes ΔE for visual spectrum and the difference of absorption of infrared light ΔZ. These variables are crucial in the process of hiding and the deciphering the contents of two graphics printed on the same place. The sizes ΔE and ΔZ result in spectral analysis twin of dyes in the space 400-1000 nm. The ZRGB camera differentiates the size of these variables enabling a parallel view of hidden and disclosed data on military uniforms.

The IRQR (infrared QR coding) procedure allows the soldier to covert acts on the battlefield and to go undetected to perform a given mission. In addition, for better integration the soldiers in the natural basis using infrared (IRD) technology, the use of "twins" allows to take on the military uniform to show the hidden information that can be encoded.

The lessons learned from past battles, as well as from current operations need to be translated to new operational requirements for the Identification Friend or Foe (IFF). Infrared design on a military uniform increases battlefield situational awareness and reduces the risk of fratricide on the battlefield. An important feature is that it does not interfere with soldiers in combat.

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