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## Topographic Maps with Infrared Colors

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### Abstract

We are introducing infrared security print as an extension for topographic map print. The article carries out the algorithm of merging several layers of spot colors. We expand the spectral analysis of dyes to the near infrared spectrum. Today's technology of topographic map multiplication uses spot colors defined by experts in the state geodetic bureau. The state map production is strictly defined by law. That indirectly emphasizes the need to protect the data displayed on produced maps. We suggest, while creating maps, adding infrared properties to the colorants for the authentication of every edition. As the official geodetic practice set RGB color values, it is possible to carry out double printing colorants for these colors, which have the same response in the visual spectrum and a different in the infrared spectrum. Based on the equalization of spectrum pairs of dyes in the visual part, a proposal was given for the degree of light absorption in the infrared region. Every publisher, printer, expert from the state geodetic bureau, determines his own level of infrared safety component participation. Such a map cannot be changed, ie; forged, thus ensuring full protection for all topographic data contained on the state map. Infrared dyes property disappears in an attempt of recording, scanning, or any other technology that allows reproduction. The visual state of the topographic map with infrared colors, is the same as the visual state of the map without the IRD extension. With this procedure there is no interference with the visual art on the map. This method of printing also allows creation of maps, with pieces of information in the visual spectrum that may not be the same as the content of information in the infrared spectrum.

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### 1. Introduction, Topographic System twins dyes

Dyes can be mixed as spot colors before printing. The layers of ink on map paper is the six-color print, eight-color print and even 20 spot color print. Topographic maps are printed with spot colors that are mixed prior to printing. Opposite: Digital printing simulates spot colors. Digital printing combines all these tones with the procedure screening C, M, Y, K process components. Mixing colors is done with an algorithm that translates digital color recordings into four-color prepress. It is a raster simulation with process dyes with unlimited number of color tones. For all colors, which are intended to be used in hiding information "twins dye" [1] procedures are introduced. Each tone color is associated with at least two dyes having different absorption properties of light in the infrared spectrum. In this matter the topographic map can be marked with graphics that will be seen exclusively at 1000 nm for which are today surveillance cameras are prepared. ZRGB cameras [2] are developed which have two different filtering of daylight. The first camera sees a wavelength Z at 1000 nm and the second camera sees a range from 400 to 700 nm. We set the systematization of dye twins [1, 3] with the aim to determine the interdependence of process dyes for the real press. Printing with known default dyes and materials set for dye application. INFRAREDGRAFIKA is a method of mutual concealment of two images. IRG becomes a method for accurately determining dye compositions in the replacement procedures of C, M, Y (Z0 state) with C, M, Y, K (Zmax state). The criteria for quality twins is equal light absorption throughout the whole range of the visual spectrum. Until the invent of INFRAREDESIGN and CMYKIR separation [4] the characteristic absorption of carbon black ink as an element to create a separate, invisible graphics, was not observed. Twins become a visual method of proper separation, transition from RGB to CMYK states respecting the CMYKIR separation. "Visual" means that the two images are composed of the same dye composition and that they are individually visible only with a projected way of looking. Since there are two images in the same place, the instrument can "see" the state of the image Z [5] and visually with the naked eye recognize the other image.

Topographic maps are printed on cartographic paper and transparent polypropylene film. Mathematical models for polymeric materials with IRG Technology, are given in the paper [6] that explains how to prepress the image that cannot be seen, and there are such hidden information on a transparent holder. Since the transparent Z / IRG is not seen with the naked eye, it doesn't interfere when using translucent maps when overlapping with other action topographic maps. Such a topographic map has a high level of protection since it cannot be photocopied, scanned or forged.

### 2. CMYKIR separation for connecting V and Z information

Classical transition from RGB color system of the CMY dyes is defined by relations given in Table 1 we use the adsorption properties of dyes in order to provoke an "infrared effect." Some dyes have a strong turnout for the Z value as the basis for the development of the theory of CMYKIR separation [7].

Table 1. Relations of Classical transition from RGB color system of the CMY dyes.

	Range 0 to 1	8 bit	4 bit	Percent %
Cyan + Red =	1.0	0 – FF	0 – F	0 – 100 %
Magenta + Green =	vector graphic	Pixel graphic	Pixel	Press CMYK
Yellow + Blue =			graphic	

Mathematical relations which enable the separation with „FSFog39“ CMYKIR standard are given with the relation  $C_{40}, M_{40}, Y_{40} = f(C_0, M_0, Y_0)$  for  $K=40\%$ .

$$Z_{40} = A^{Fsfog39} * T ; \tag{1}$$

Z<sub>40</sub> values of process coverage dyes were determined at 40% carbon black ink.

$$Z_{40} = \begin{bmatrix} C_{40} \\ M_{40} \\ Y_{40} \end{bmatrix} ; \tag{2}$$

Independent variables CMYKIR separations are given in the vector (3), and additional links in the relations:

$$\mathbf{T} = \begin{bmatrix} G_M \\ E_Y \\ D_C \\ Y_0 \\ M_0 \\ C_0 \\ 1 \end{bmatrix}; \quad (3)$$

$$\begin{aligned} D_C &= \frac{C_0}{M_0} + \frac{C_0}{Y_0} \\ E_Y &= \frac{Y_0}{M_0} + \frac{Y_0}{C_0}; \\ G_M &= \frac{M_0}{C_0} + \frac{M_0}{Y_0} \end{aligned} \quad (4)$$

Matrix  $\mathbf{A}^{\text{Fsfo39}}$  denotes the parameters of linear regression at 40% coverage of black carbon offset dyes for special protected paper. For each combination of dyes and paper this matrix is specific. For the paper (coated) on which postage stamps are printed, the coefficients of regression relationships are:

$$\mathbf{A}^{\text{Fsfo39}} = \begin{bmatrix} 2.28053 & -0.78802 & -1.47864 & 0.12248 & -0.22929 & 1.63392 & -57.916 \\ -2.59669 & -4.83079 & -0.02830 & 0.08817 & 1.40283 & -0.35638 & -11.576 \\ -3.60028 & -4.85615 & 6.18267 & 1.63614 & 0.01668 & -0.3095 & -32.836 \end{bmatrix} \quad (5)$$

A matrix carrying values for linear regression is calculated on the basis of measurements of twin dyes in a wide range of CMYKIR separation and the merge of two images. [3, 7] The proposed relations and parameters (5) for the merger of two images with CMYKIR separation of input and output values of C, M, Y are given in percentages. These relations can be applied for concealed Z graphics as text is rasterized with a spiked grid [8]. We apply the individualized rasterization in INFRARED GRAPHICS comprising of one tone text.

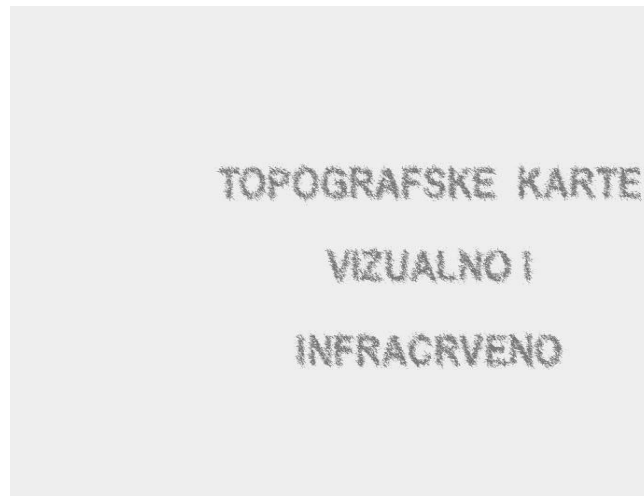









Fig. 1. Planned hidden text rasterized with a spiked grid.

When we are hiding text we want that he is exactly the same in the entire area of the infrared spectrum. Such a task of "uniformity" requires that all spectrums end in the Z point at 40% coverage. It is a decision for the examples given in this article. We use 40% of twins in the infrared spectrum, the Z value is the same for all the colors in the infrared spectrum, regardless of whether it is blue, light blue, black or green. The default Z graphics (Figure 1) is

subject to the relations (1) to (5). The values of the colors in the RGB system are given in Table 2. These values run a transformation toward the CMYKIR separation.

The ZRGB camera will separate the visual from the infrared spectrum. Digital topographic maps are printed with process dyes whose values are given in the Table 2. Places with the hidden Z graphics will be printed with CMYK values "Set of Z dyes." Places on the map that have no background with the Z graphics, will be printed with the values of the "Set of V dyes."

Table 2. Twins dyes for topographic maps.

Colors	Set of V dyes, % C <sub>0</sub> , M <sub>0</sub> , Y <sub>0</sub> , K=0%	Set of Z dyes, % C <sub>40</sub> , M <sub>40</sub> , Y <sub>40</sub> , K=40%	Swop coated Color setting	R, G, B colors 2 <sup>8</sup> , 0 - 256 level
Green	79, 55, 74	65, 30, 64		54, 113, 66
yellow ochre	35, 37, 78	0, 11, 66		166, 159, 56
light blue	67, 50, 37	45, 27, 15		82, 126, 158
dark blue	77, 70, 54	59, 50, 33		58, 77, 118
dark red	48, 88, 71	13, 81, 55		132, 31, 74
Sepia	49, 62, 79	18, 46, 70		129, 96, 52
Black	79, 82, 79	62, 68, 68		53, 44, 54

Application of infrared graphics in cartography will be individualized to the Geodetic Institute. The first stage of individualization is to determine the Z value for the use of dual colors. It is proposed to maximize the number in order to get a stronger infrared effect visible with the ZGRB camera [2]. Each color can be determined by the maximum Z. We will use that when printing in offset. Because digital printing has its limitations, different solutions are possible.

### 3. Layered topographic map color composition

The Sixcoated system is shown in Figures 2 to 7. The colors for process printing are displayed only in the merger of the six spot colors. For this the CMYKIR prepress is applied to connect two pieces of information: visual and infrared. Before the printing process can be viewed channels that show "substraction" and reduction of the process coverage due to the Z image, which is intended for the infrared spectrum.

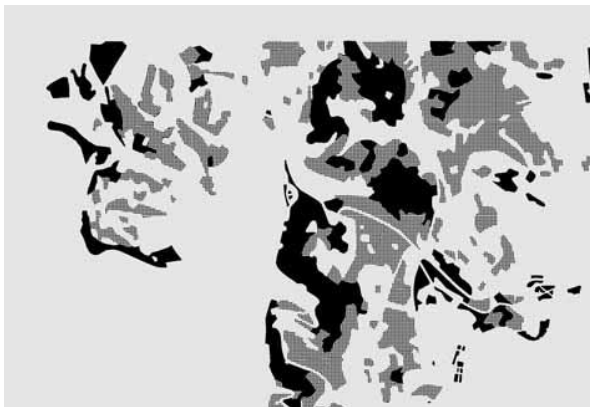


Fig. 2. Parks and green areas.



Fig. 3. Green; fences.

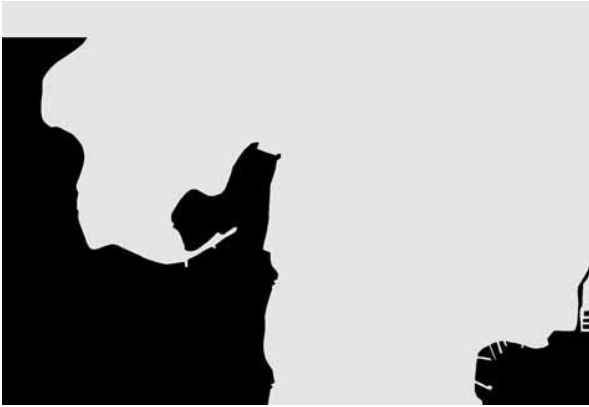


Fig. 4. Light blue; see and land.



Fig. 5. Dark blue; rivers and sea depth.

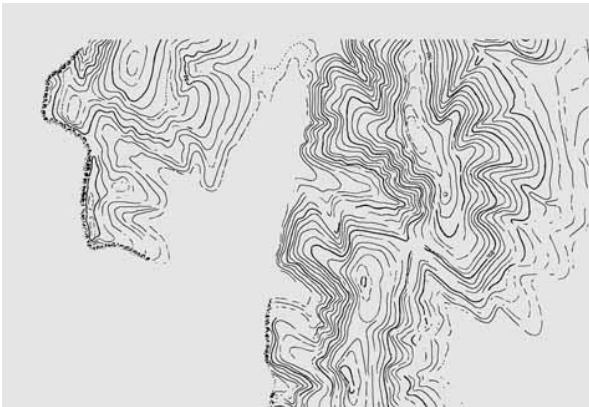


Fig. 6. Sepia; terrain heights.

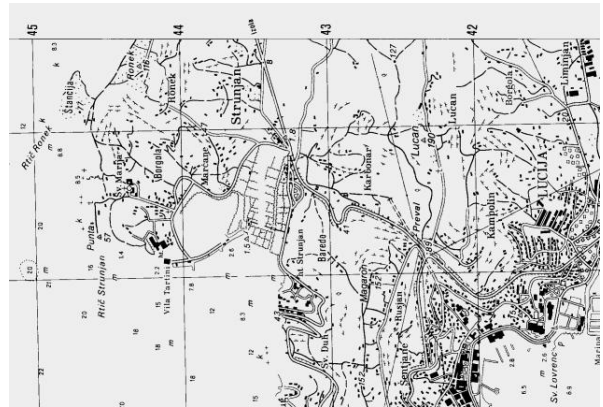


Fig. 7. Black; houses, measure, names, roads.

The layers of topographical colors are suitable for editing and printing with spot colors. This is the original recording from which different maps are merged, parts of the maps and the preparation for the CMYKIR separation. In the offset print we introduce two parameters: the transparency of dyes and the order of dye print. Black color is usually not transparent, and hinders the free choice of the order of printing. Experiments with black dyes are shown in the article where only this dye is used in two independent states for the display of the hidden part of the information. Separated are information about cities, houses and roads that are visually processed with black [9]. In the digital print colors were transformed into the CMYK process colors. An important element is the sequence of the coverage. The example in this article has 6 different colors for which the brightest color (Sepia), which determines the height of the terrain, was applied last. In the contrast the dark blue color that indicates the depth of the sea was carried out after the water surface so that the light-blue color doesn't cover the information about depths. The last color is black because it carries the names of cities and other important information. In offset printing as opposite, that element is not important because the color is transparent. For determination of the position of the very parts of the image, the print with the black color is first. None of the other offset colors will cover the black.

We are discussing this to emphasize the difference in the preparation of digital printing forms for the offset printing and digital print, although both preparations starts from the same spot channel like examples in Figures 2 to 7.



#### 4. Topographic map in the visual and infrared spectrum

Each layer has its given visibility. Images 2 to 7 were prepared for the visual spectrum. Merging Figure 1 with other layers will provide the security of topographic map which carries the information for the ZRGB camera [2]. On the conference IC / Toronto 2013 [9] IRG system separating one (black) layer into visible black and into the IR - Z black has been proposed. The black color is used for information on urban amenities, topographic network and roads. In this paper we propose to merge all layers in the RGB color system from which derives CMYKIR separation [4] for the theory of IRD [7].

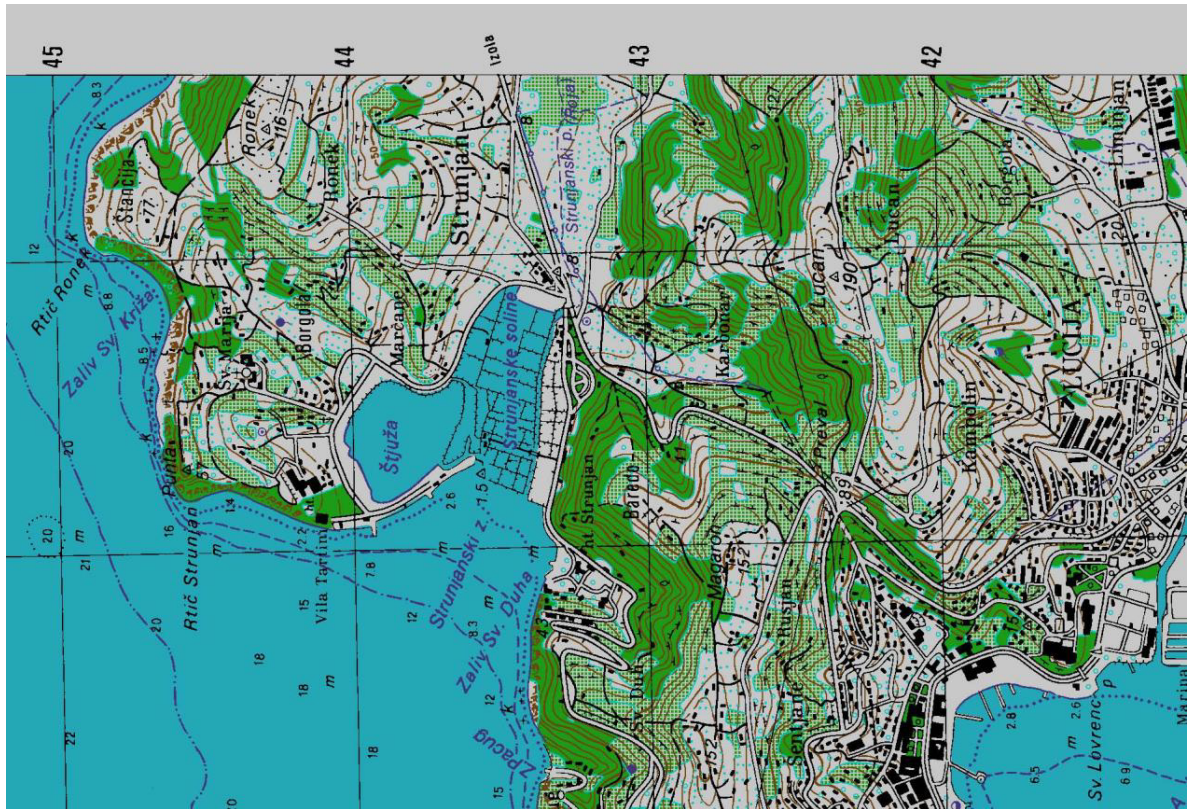


Fig. 8. Map in color, produced with CMYKIR merging of V and Z images.

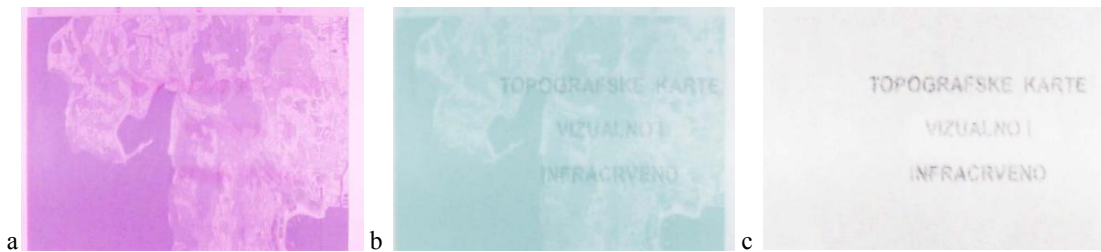


Fig. 9. Scanning of topographic map with barriers: (a) 570, (b) 715 and (c) 1000 nm.

The Z input image (Figure 1) differs from the Figure 9 that will be seen on the Z camera of 1000 nm. These deviations are expected since the topographic map has colors with a low coverage, up to the white area. The excerpt from the input and output image Z "TOPOGRAF" is shown in Figure 10. Infrared graphic is reduced. It depends on

the topographic map and the position of the Z graphic.

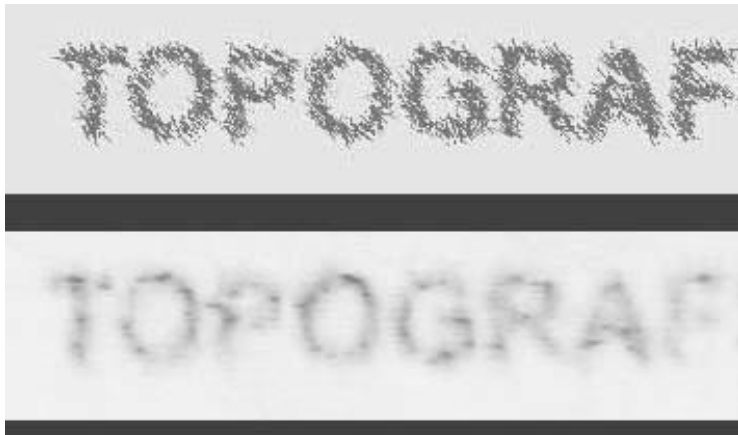


Fig. 10. The default input Z picture and produced Z image at 1000 nm.

Topographic maps are made in two graphic forms; as pixel digital 8-bit recording and as vector graphic. Vector lines are "sepia color" used for presenting information about height of land. The design of the vector graphics is shown in the paper [10] at the conference DAAAM 2010 as infrared protection in the press. The mathematical basis for the definition of transformation parameters for Bézier curve is given with the application to INFRAREDESIGN procedure of hiding information on the documents. Such a system would be applied in the implementation of safety of topographic maps. Hiding of information on the topographic maps has a dual purpose. The first one refers to the increase of safety system for reproduction and print. The second implies the introduction of additional information on topographic maps, these having a special informative purpose. Such information can be detected only by using the special infrared cameras [11].

With infrared graphics we provide continuity of desired tone on all maps, such as the color of water (sea) that are larger areas that we want to have equal tones on the entire map package. We also want the continuity of tone on the areas of forest, meadows and rivers.

As each topographic map serves as a convenient medium in the geodetic business, it is of great importance not only the accuracy but also the safety of the geodetic data and metadata. Bases of geodetic data are prepared and provided at the state level. Misinterpretation or false presentation entails legal and criminal consequences. It is possible to ensure maximum security and confidentiality of the data presented using the infrared graphics printing features. For example, the standards for which are made of military topographic agreed the framework of NATO. Standardization is covered by way of making military topographic maps of cartographic databases, following the rules and philosophy of geoinformation systems (GIS). The same rule applies when creating thematic and / or other types of cards. The aforementioned aspects of the accuracy and security of information printed in the infrared region of the press ensure the quality and intensity stronger than the usual print only using the visible part of the spectrum.

The hidden image, hidden text information (Figure 10) by the method of IRD or "infrared graphic printed procedurs" is performed on a HP plotter. For each toner, ink and paper combination a new finishing is necessary within the parameters presented here, through the relation 1 to 5. Many authors conducted extensive research on printers [12], especially in the analysis of black toner which is important for us in the IRD process of information duplication. Different spectroscopy methods are used to determine the color equalization of color twins. For the purposes of this study, colors and dyes are analyzed with the forensic instrument "PROJEKTINOVA" [13]. There has been a high degree of equalizing the visual (V) and infrared light absorption in V and Z [5] spectrum. In the digital press, changes in pigment are shown over time. Studies have shown that the decisions on the selection of dyes which have a longer stability is vital. Some authors have investigated this phenomenon [14] which is very important for the idea of image hiding. The question they have set was: "How has the usage of colors changed over time?". Our dye tests with the associated spectroscopy last a few years, especially in the area of paintings reproduction [14]

which have a double condition: for the visual and infrared spectrum [15]. The goal was the appearance of the same double state in the graphic reproduction as in the original art painting: in the V and Z range.

## Conclusion

The problem is to improve, enhance the security and credibility of topographic maps in civilian and military applications. We introduce INFRAREDGRAPHIC onto topographic maps. We publish a mathematical model of the separation and merger dyes which become carriers of double-separated state of the visual and infrared detection.

With the introduction of twin dyes with the same response in the visual but different in the infrared spectrum a new protection is set in the map press. For the given dyes double dye spectrograms are calculated. On the basis of the calculation a proposal for a degree of absorption of light in the infrared area, which are determined individually by the user. This allows individualized level of safety infrared components participation within individual topographic information. Infrared graphic in the cartographic system is a new field of protection of all owners in the steps of producing topographic maps. Introduced are methods of breaking spot color and the method to merge two images using CMYKIR separation according to what kind of results we want and what kind of technology we have available. Infrared protection is drawing into all parts of the printing process, not visible to the naked eye serving as the control of the dye mixing. The map protected by twin dyes can't be forged, ie. Its authenticity is easily determined. Any attempt tampering with the map removes the infrared component. The technology of Infrared graphics will have a new role in the field of topographic information - balancing the color tones of large projects. Any error in color shades in the press gives a result of visibility of the Z graphics that should be hidden. This paper is posing a problem, provides solution and suggests a protection of topographic maps with infrared print, supported by INFRAREDGRAPHIC procedure.

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