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Selection and Verification of Camouflage Colors

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Abstract The paper describes a methodology used for analyzing data generated in the natural environment and in real time based on proprietary computer program developed by the authors. Directions for further work geared towards determining the number of colors in camouflage. The ones which would ensure the highest level of camouflaging efficiency for a soldier's uniform and for a given area were indicated. The necessity was demonstrated of conducting research aimed at developing a specific color palette for the purpose of perfecting camouflage patterns dedicated to a specific climatic- and geographical zone in which the object would not be distinguished from the background of the terrain.

Introduction

The dynamic development of reconnaissance systems operating in various ranges of electromagnetic radiation has still not eliminated the importance of reconnaissance, in particular the 400 ÷ 700 nm wavelength range. Optical reconnaissance in the visible range is based on the motion, shape and color detection. Due to the specific structure of the human eye, movement is detected immediately after it occurs, and that is why it is an “unmasking” feature. Many predators utilize this fact, and despite them having advantage of speed during the attack, they purposefully freeze to become imperceptible, waiting for the right moment to attack as it gives them the best chance of success. Later in the article, the authors focus on the selection of camouflage colors as an element reducing the contrast of the object in relation to its background.

The color is mathematically described by three components: L – brightness (luminance); a – component determining the shade from green to magenta; b – component determining the shade from blue to yellow.

The CIELAB color space is described by the following equations:

$$L = 116\sqrt[3]{\frac{Y}{Y_0}} - 16 \quad (1)$$

$$a = 500\left(\sqrt[3]{\frac{X}{X_0}} - \sqrt[3]{\frac{Y}{Y_0}}\right) \quad (2)$$

$$b = 200\left(\sqrt[3]{\frac{Y}{Y_0}} - \sqrt[3]{\frac{Z}{Z_0}}\right) \quad (3)$$

where:

X_0=94.81

Y_0=100.00

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Z_0=107.30

are the color coordinates of a standard white body.

The method of describing color via Lab coordinates is currently the most popular one and forms the basis of color management systems.

In order to analyze the possibilities of color discrimination, one can use a mathematical relationship describing the difference between the location of points of different color within the CIELAB space:

$$\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2} \tag{4}$$

where:

0 < ΔE < 1 – observer does not notice any difference;
1 < ΔE < 2 – only experienced observer notices any difference;
2 < ΔE < 3.5 – also inexperienced observer notices the difference;
3.5 < ΔE < 5 – observer notices a clear color difference;
5 < ΔE – observer perceives two different colors.

Another important element of great impact on the ability to distinguish an object from its background is the optical contrast between any two colored surfaces. Optical contrast can be determined analytically, based on the determined spectral characteristics.

The *k* contrast is calculated from the following formula:

$$\boldsymbol{k} = \frac{\boldsymbol{\beta_A} - \boldsymbol{\beta_B}}{\boldsymbol{\beta_A}} \tag{5}$$

where:

k – contrast;
β_A – luminance of the color whose luminance is higher;
β_B – luminance of the color whose luminance is lower.

$$\beta_A = \sum_{\lambda=400nm}^{\lambda=700nm} Y(\lambda) R_A(\lambda) \tag{6}$$

where:

$Y(\lambda)$ – coefficient dependent on the wavelength;
$R_A(\lambda)$ – reemission coefficient for a specific radiation wavelength of sample A.

$$\beta_B = \sum_{\lambda=400nm}^{\lambda=700nm} Y(\lambda) R_B(\lambda) \tag{7}$$

where:

$Y(\lambda)$ – coefficient dependent on the wavelength;
$R_B(\lambda)$ – reemission coefficient for a specific radiation wavelength of sample B.

Materials Research Proceedings **17** (2020) 79-85 https://doi.org/10.21741/9781644901038-12

Analysis of the terrain background based on the determination of the number of camouflage colors and their coordinates

Software environment and graphic design of the program. This section describes a software environment and graphic design of the program for the analysis of the background of the terrain in terms of determining the amount of camouflage colors and their coordinates. Visual Studio 2010 C # programming environment with the .NET Framework ver. 4.0 platform was selected to write a program for the background of the terrain, as far as the determination of the amount of colors, together with new tools and libraries, as offered by AForge.Net and Accord.Net in terms of scientific calculations, image processing and robotics are concerned. The selection of AForge.NET and Accord.NET libraries for writing the above program was not accidental because its development (advancement) is directed towards more complex algorithms for video signal processing (both images and sound signals), e.g. creating histograms, color reduction, edge detection, quantizing, calculations of the Fourier transform, etc.

When designing the user interface (Fig. 1), simplicity, minimization of information available in the application window and placement of interactive elements (widgets) are all taken into account. Individual fields and control buttons are clearly defined by descriptions, which are easily recognized by the user.

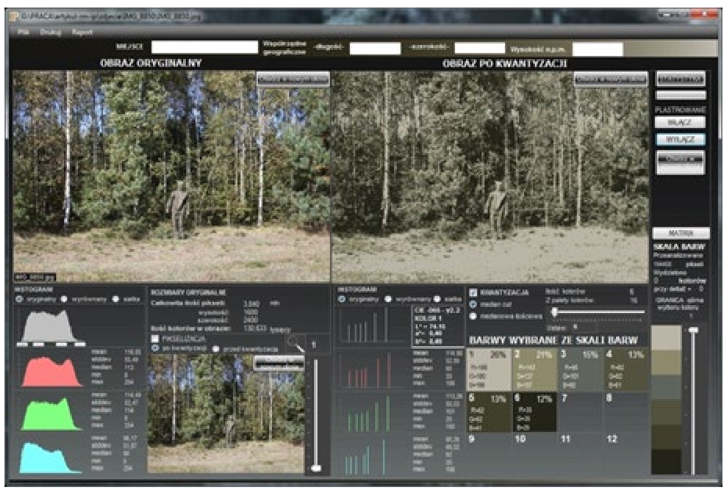

Fig. 1. Graphic interface (software window)

Background analysis in order to select representative colors. The application presented above is used as a tool enabling image processing (in the form of a photograph in any format) captured in the field during analysis of the background of the terrain. It is also used to verify a dedicated camouflage pattern. Proper selection of the main colors using the program is conditioned on initial digital photograph development process using e.g. Adobe Photoshop Lightroom software.

Background analysis is based on a non-linear static mapping of the image color matrix in the x, y plane by limiting the set of their values. The input values for a single color pixel (R, G, B) in the photograph (Fig. 2) are associated with the levels of representation which are assigned to a given range (number of colors). This process is called vector quantization implemented according to the median cut algorithm. As a result of the above operation, a reduced image (visible in Fig. 3 and 4 window on the right hand side) is obtained, with the number of given colors and with simultaneous display of those colors in individual windows in the order of percentage.

Materials Research Proceedings **17** (2020) 79-85
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Fig. 2. Background image of the area subjected to color analysis

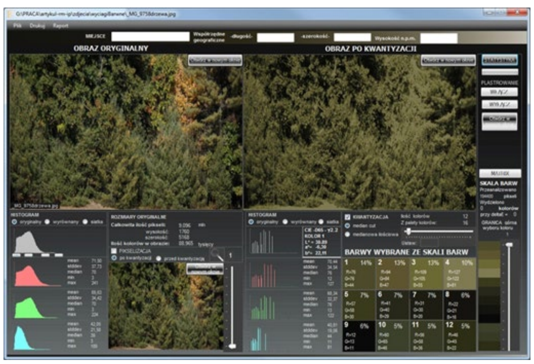

Fig. 3 Background of trees subjected to color analysis

Fig. 4. Background of grass subjected to color analysis

Fig. 5. Reports generated by the program containing data from color analysis

Development and verification of camouflage pattern

The stage of developing camouflage for the field uniform is divided into several phases, appearing in succession:

- determining the amount of camouflage colors;
- averaging the color coordinates for different sceneries and seasons;
- determining the percentage of individual colors;
- developing a camouflage pattern.

The exactness of the above- described process is verified as a result of a multi-stage testing of the product in real conditions. Verification during the camouflaging efficiency testing is based on a subjective assessment of the degree of concealment, the object hiding against its background, as determined by the distance between the object tested and the observer. This distance at which the detection occurs (detection in this case means confirmation of the presence of an object of potential military significance in the region under observation) is measured in meters.

The proprietary program described above also allows the user to verify the developed camouflage both in real time – during field tests – and by analyzing the images captured performed during the said tests.

Military uniforms with new camouflage patterns, the so-called spring-summer and autumn-winter underwent verification testing. The current field uniform, as used by the Polish Army, in the *Panthera* camouflage pattern (forest version) was used as a comparative uniform on selected images. All the tested camouflage patterns were developed for use in Central European conditions. Selected colors of these camouflages were chosen on the basis of analysis of forest areas in Poland where they provide the required degree of concealment.

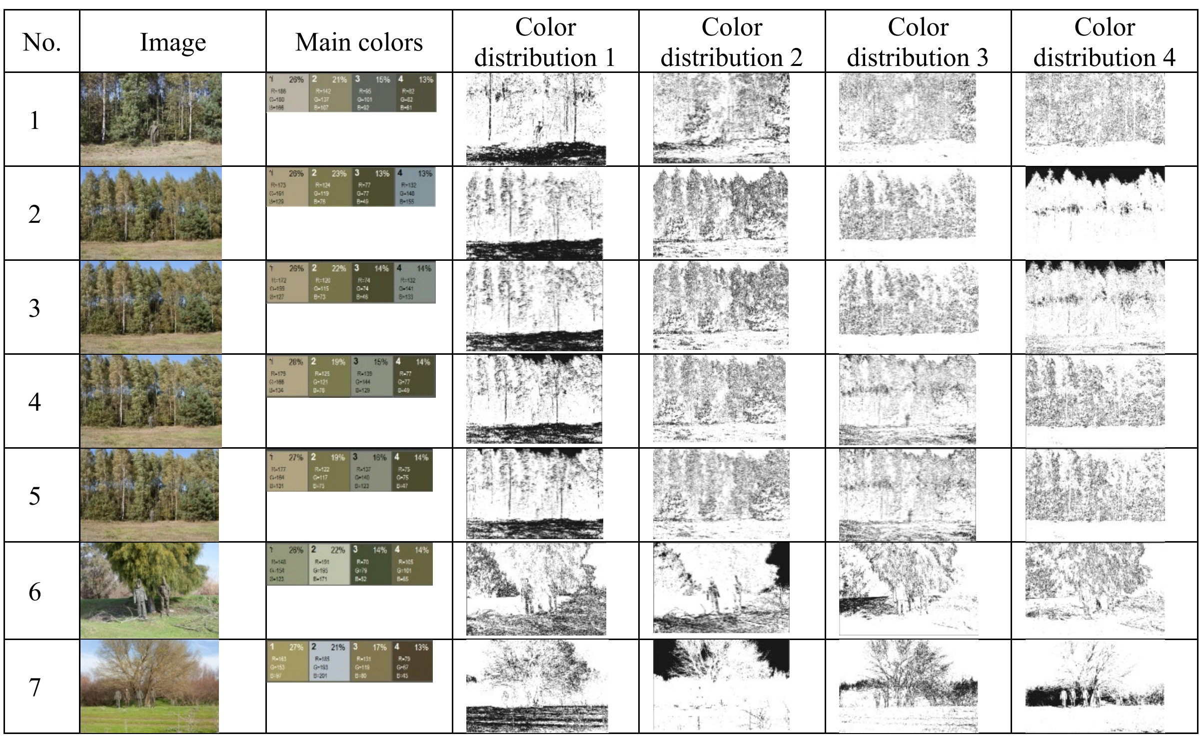

Fig. 6. The results of the background analysis of the terrain in terms of the correct selection of camouflage colors. Imaging area 1-5 – Poland. Imaging area 6, 7 – Andalusia, Spain.

Materials Research Proceedings **17** (2020) 79-85 https://doi.org/10.21741/9781644901038-12

The results of the analysis of the images captured during the tests of uniform camouflaging efficiency against the background of representative of the scenery in Poland (items 1 ÷ 5) are presented in Fig. 6. By a selective display of the image after averaging it to a certain number of colors, information on the degree to which the colors and camouflage pattern match the background of the terrain is obtained. A similar series of tests was carried out for another climate zone (Andalusia region in Spain, items 6 and 7). The findings were unambiguous. Camouflage patterns developed for use in the Central European zone exhibited lesser camouflaging efficiency in the Mediterranean climate zone (no matching of the camouflage color to the background of the terrain – the photographs clearly reveal human silhouettes).

Summary

The conducted analysis unambiguously confirms the thesis about the necessity of carrying out projects aimed at selecting colors best suited for the uniform(s) used by a soldier during the performance of their official duties in various regions of the world.

Bearing in mind the manner in which the Polish Armed Forces operate during modern conflicts, and considering the possibility of troop deployment, there exists a tangible need to develop a color palette dedicated to be used in the design of camouflage patterns suitable for specific climate zones. Soldiers on peacekeeping missions in other regions of the world should be equipped with uniforms adapted to the place where they are to serve. A dedicated uniform is the fundament of passive protection for a soldier.

On the contemporary battlefield, recognizance systems are increasingly based on infrared detectors. This aspect should be considered when printing the camouflage pattern, dying the uniform fabric and developing dyes used for this particular purpose.

At present, intensive works are underway to develop reconnaissance equipment based on multispectral imaging, which covers the visible-near infrared (NVIR) and short-wave infrared (SWIR) spectral ranges, which is widely used, e.g. in agriculture, to assess the degree of crops vegetation or in forestry, to assess the occurrence of pest infestation. Multispectral imaging allows for the measurement of radiation energy intensity in a given range of coordinates and wavelengths defined as a function of $I(x, y, \lambda)$, where x and y are the coordinates of the imaged surface and λ is the wavelength. The results of the analyses are diagrams called re-emission curves.

Military Institute of Engineer Technology devotes a great deal of effort to the analysis of the background of the terrain using advanced image recording techniques, namely multispectral imaging in the range of 380 nm ÷ 2800 nm, including the so-called NVIR and SWIR spectral ranges. The works conducted are aimed at determining the boundaries, within which the re-emission curves of colors reflecting the natural environment in the range of electromagnetic wavelengths not yet defined and not considered when developing camouflage patterns should be contained. These boundaries are vital from the point of view of the features characterizing reconnaissance equipment and their capabilities .

References

[1] M. Laprus (ed.), Leksykon wiedzy wojskowej, MON, Warszawa, 1979.

[2] B. Fraser, C. Murphy, F. Bunting, Real World Color Management, 2nd Ed., Peachpit Press, San Francisco, 2004.

[3] Polska Norma Obronna NO-80-A200, Farby specjalne do malowania maskującego. Wymagania i metody badań, 2014.

[3] M. Pearrow, Web Site Usability Handbook, Charles River Media, Boston, 2006.

[4] S. Prata, C++ Primer Plus, 5th Ed., Sams, Indianapolis, 2004.

[5] A. Troelsen, P. Japikse, Pro C# 7 with .NET and .NET Core, Apress, New York, 2017. https://doi.org/10.1007/978-1-4842-3018-3

[6] AForge.NET, http://www.aforgenet.com/aforge/framework/, (access date 2019.11.08)

[7] Accord.NET Framework, https://code.google.com/p/accord/, (access date 2019.11.08)