A Concept of Virtual Reality in Military Camouflage Application

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Abstract: Camouflage, and in particular one of its forms – military camouflage – is the basic form of protecting friendly forces against the enemy. The article presents the concept of a virtual method, which, based on a photographic simulation for various sceneries and seasons, would allow for testing of camouflaging efficiency in laboratory conditions. The method of image acquisition and attributes which should characterize those images in order for them to be used in photographic simulation was discussed. Furthermore, parameters necessary for a correct visual synchronization of the camouflage patterns applied on objects with the images were presented. Attention was paid to the capabilities and limitations of human vision in the context of military reconnaissance. Methods ensuring colour fidelity during image processing were included, as was selected information on camouflage itself and design of camouflage patterns. The test workstation and the required parameters of the equipment used to conduct camouflaging effectiveness studied in virtual environment were described, and a general algorithm for the virtual method of camouflaging effectiveness assessment, as well as the method of calculating this evaluations were proposed. The method was tested on the example of a Leopard 2A4 main battle tank with a newly-designed camouflage pattern dedicated to autumnal deciduous forest of Central Europe.

Introduction

The idea of using virtual reality for military purposes, mainly in training, has recently become very popular [1]. The biggest advantage of using the virtual method is lowering the costs, because all the operations will be carried out in place; what will be changing, however, will be the scenery in virtual reality.

One of the factors of key importance for the armies at contemporary battlefield is the capability to conceal their activities from the enemy, i.e. appropriate camouflage [2]. Military camouflage is a kind of safeguard for combat operations, and it consists in hiding forces and material from being identified by opponents or misleading them about the location of its own forces [3]. One of the ways of concealing the forces is to use camouflage, i.e. selecting colours, shapes and sizes of splotches in order make it difficult to distinguish the camouflaged objects from the background of the terrain.

In terms of the camouflage pattern, two main types of patterns can be distinguished – the mimetic pattern and the disruptive (dazzle) pattern (Fig. 1). Mimetic camouflage is a type of camouflage pattern whose main function is to cause the object to blend into its background of the terrain (crypsis). This function results from the need to avoid being detected by the observer who "sweeps" the area using spatial vision. However, the function of the disruptive pattern is to break the shape of a given object, so that it is significantly harder for the observer to recognize the shape and then classify or even identify the object. This effect is achieved by using large splotches of contrasting colours.

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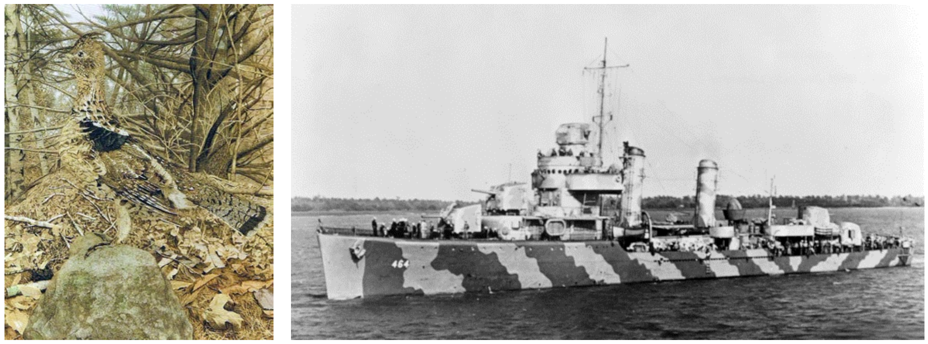

Fig. 1. Plumage pattern – mimetic [4] and USS Hobson off Charleston vessel (1942) in dazzle camouflage [5]

The parameters used to determine whether a given camouflage does perform as it should is to assess camouflaging efficiency, which is usually carried out in field observations, during which, a group of observers determines the degree of visibility of objects in the background. This is done for a specified period of time and from exact distances in the environments with defined parameters. The degree of visibility is estimated according to the scale below:

- **No detection** – confirmation of the absence of an object of potential military significance in the area under observation;
- **Detection** – confirmation of the presence of an object of potential military significance in the area under observation;
- **Recognition** – determination that the object detected is a specific type of object, e.g. a human, a wheeled reconnaissance vehicle, camouflage net;
- **Identification** – determination that the object recognized is a specific type of object, e.g. the recognized human is a soldier and the particular tank is Leopard 2A4.

The main “surveillance instrument” analysed in this field is the human eye. Its physical focal length is about 17 mm, but taking into account the fluid filling the eyeball, the commonly accepted value of 22 mm can be assumed. The pupil can change its diameter in the range of approx. 2 ÷ 8 mm, which corresponds to brightness equal f/2.75 ÷ f/11.

The angle of view in humans is approx. 150° – horizontally and 130° – vertically, but sharp vision is about 20°, and the field of maximum clear vision is 5°. This stems from the concentration of receptors – suppositories around the macula – which is 200 000/m^2 [6]. Assuming that one suppository is responsible for creating one impulse responsible for creating the impression of vision (this actually happens only for the central part of the retina [7]), where the minimum angle of view α is 10" (arcseconds) [8].

The number of suppositories in one eye is estimated at about 6 million, which makes it possible to distinguish 160 colours and 600 000 shades.

According to Young-Helmholtz's theory, the human eye has three types of suppositories, and each of these types is sensitive to stimuli from a certain range of a visible spectrum of electromagnetic radiation (Fig. 2). These are:

- the long-preferring ones (stimulated mostly by long wavelengths – L – maximum sensitivity of ca. 565 nm);
- the middle-preferring ones (stimulated mostly by medium wavelengths – M – maximum sensitivity of ca. 530 nm);
- the short-preferring ones (stimulated mostly by short wavelengths – S – maximum sensitivity of ca. 420 nm.)

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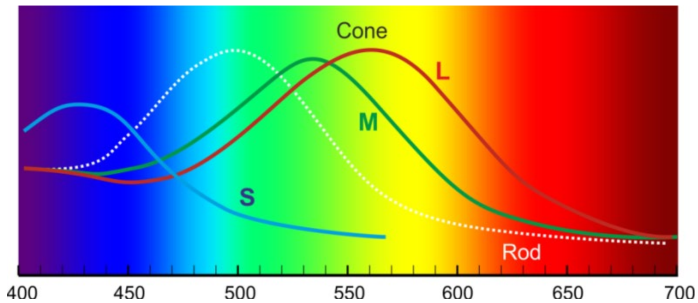

Fig. 2. Diagram of the wavelengths stimulating individual receptors [9]

The purpose of the project was to develop a concept for a virtual method of assessing camouflaging efficiency for camouflage patterns, which, taking into account the capabilities of human sense of sight and based on background images for various sceneries and seasons, would allow for testing of this efficiency to be conducted. For this purpose, a proposal has been prepared concerning a laboratory workstation for testing camouflaging efficiency in real conditions which had been imitated. The paper presents examples of photographs of summer scenery with a simulated battle tank contour.

Methods and materials

Images. The basis of a photographic simulation is a library of images of the natural environment captured in many sceneries and in various seasons. Based on the available image library, sample summer scenery image was selected. The image should be characterised by adequate quality both in terms of the amount of information (image size) and the colour (range and colour accuracy – Fig. 3). The colour and white standard (X-Rite ColorChecker Passport Photo) was used for calibration. Each image contained not only the metadata about the camera with which it was acquired, but also the information on the geographical location, the scenery, the time of year, day and distance from the background.

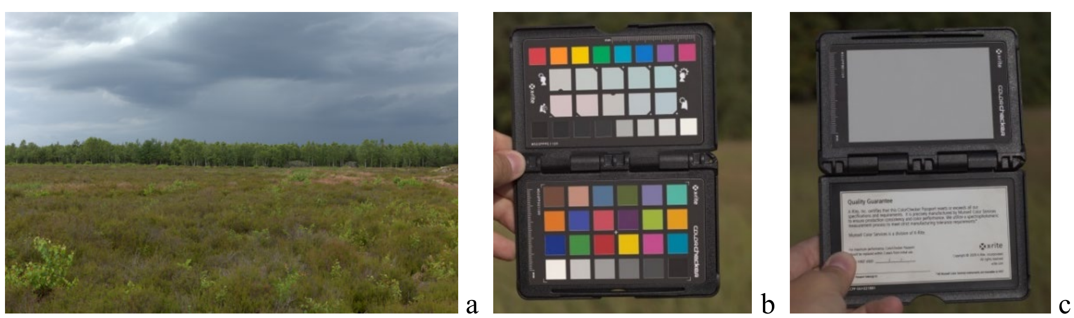

Fig. 3. Image capturing (a) using colour standard (b) and white standard (c)

Samples. The test model was a 3-color camouflage pattern. It was generated as a random set of points using Voronoi tessellation for Chebyshev distance and with 33.33% percentage of each colour (Fig. 5a). The contour of the Leopard 2A4 MBT in service with Polish Armed Forces from the 10th Armoured Cavalry Brigade [10] (Fig. 5b) was used as the camouflage carrier.

Before attempting to evaluate camouflaging efficiency, the sample (understood here as camouflage applied onto the vehicle) required visual synchronization with imaging. The scope of synchronization included adjusting the scale, colours, and chiaroscuro using Photoshop (Adobe, San Jose, CA, USA) raster graphics editor and Blender (Blender Foundation, Amsterdam, The Netherlands) 3D creation suite.

The scale was adjusted based on the known equipment dimensions and distances shown in the images (Fig. 4).

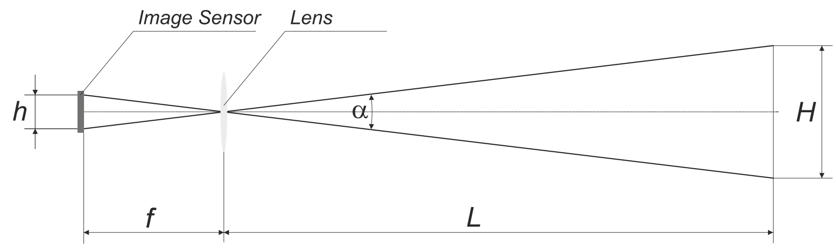

Fig. 4. Diagram for the proposed captured images. Symbols: H – photographed area, L – distance to the photographed object, h – image sensor size, f – focal length, a – angle of view

$$H = h \cdot L / f \tag{1}$$

Maintaining uniform colour scheme made the use of one common colour space possible – Adobe RGB and one common colour model – CIE L * a * b *. In addition, all the images were taken with a calibrated camera and had white balance adjusted based on the white standard (Fig. 3).
By using a 3D object and illuminating it with virtual light consistent in the direction of the image, the required chiaroscuro was obtained (Fig. 5c and d).

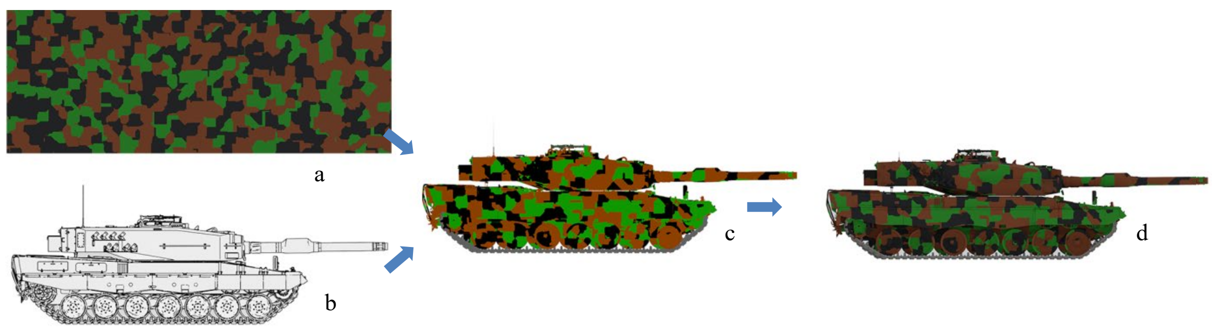

Fig. 5. Pattern application (a) onto an object (b, c) and generation of chiaroscuro characteristic for the given season and time of day (d)

Laboratory workstation. The proposed laboratory conditions for virtual assessment of the camouflaging efficiency included a projection screen, an observer workstation equipped with a keyboard and a mouse and a supervisor workstation equipped with a control computer (Fig. 6).

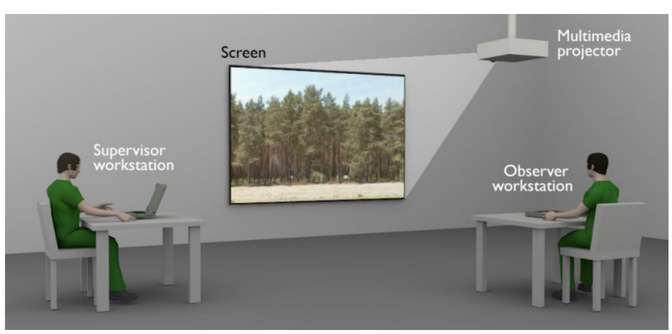

Fig. 6. Drawing of test workstation

Calibration of the presented images (on computers and screens) and the use of the *Color Management System* ensured that the human perception of colour accuracy for images was maintained during the tests (Fig. 7).

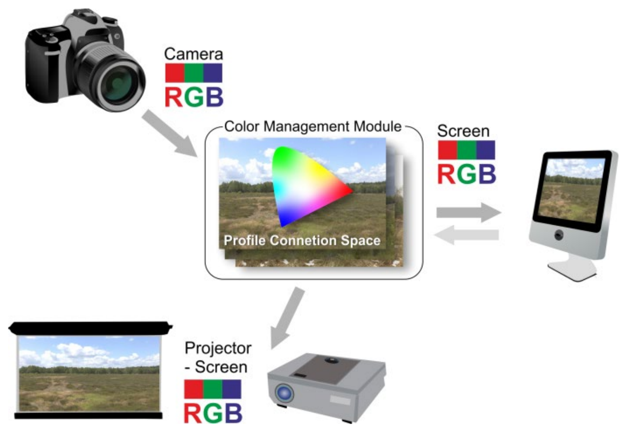

Fig. 6. Digital Colour Management System laboratory workstation

Test results. The aim of the study was to determine the camouflaging efficiency of a selected object covered with a camouflage pattern in different sceneries. To determine this value, a number of tests should be performed, and the result should be arithmetic **means** from detection, recognition and identification **distances**. In the Polish Defence Standards, the **average** from the recognition distance is usually used.

The first step was to determine the conditions required for a stationary laboratory which would be used to perform tests of camouflaging efficiency using virtual reality. The laboratory design should take into account all the requirements related to the essence of research consisting in observation of a series of images and determination of the degree of visibility of objects against their background in virtual conditions, however, as close to real circumstances as possible.

In order to create the impression of observation of the examined objects in the field as faithfully as possible, it is necessary to specify the distance between the observer's workstation and the screen L_e (2) (Fig. 4). This, in turn, depends on the screen parameters and imaging,

$$L_e = S_e \cdot L / S = H_e \cdot L / H \tag{2}$$

where:

H, S – height; actual width of the photographed fragment of the background [m],
H_e, S_e – height; width of the image presented on the screen [m],
L – distance of the observer to the object [m],
L_e – distance of the observer from the screen [m].

The rules for presenting images were set out based on the Polish Defence Standard [11], which describes field methods of conducting camouflaging efficiency assessment tests. Therefore it was assumed, in accordance with the said standard, that the order of displayed images should be from the furthest to the nearest distance, and that the time of presenting the image to the observer should be no longer than 2 min. The series of tests is considered to be completed after the imaging has been presented from the shortest distance or after the object has been identified.

Additionally, it was assumed that at least two series of images should be available for a given environment. Furthermore, for one series (including all the simulated distances) the location of objects is not to change, whereas for the second series the object is located in a different place for each distance.

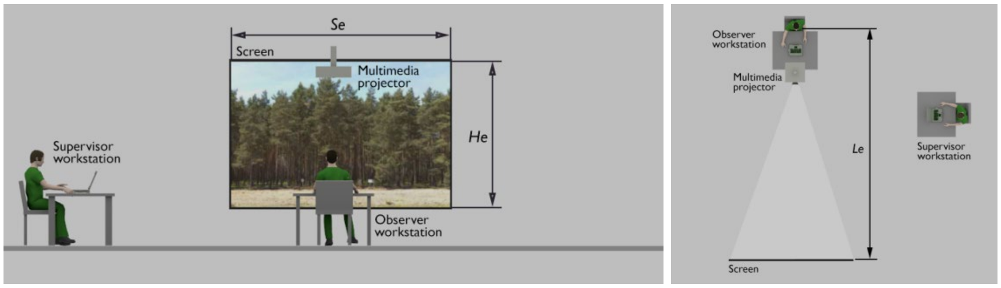

Fig. 7. Parameters of test workstation

To support the research process, a computer program was designed which, among others, controls the display of images and records the results (Fig. 9).

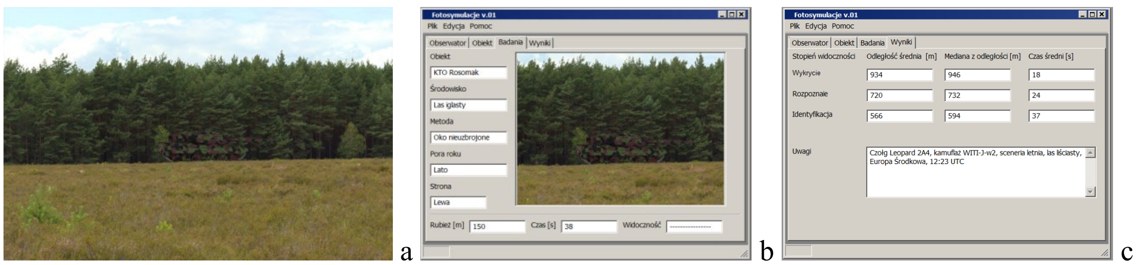

Fig. 9. View of the observer screen a) and the supervisor b) c) during the test

The general algorithm of the research methodology using the program is shown in the diagram (Fig. 10).

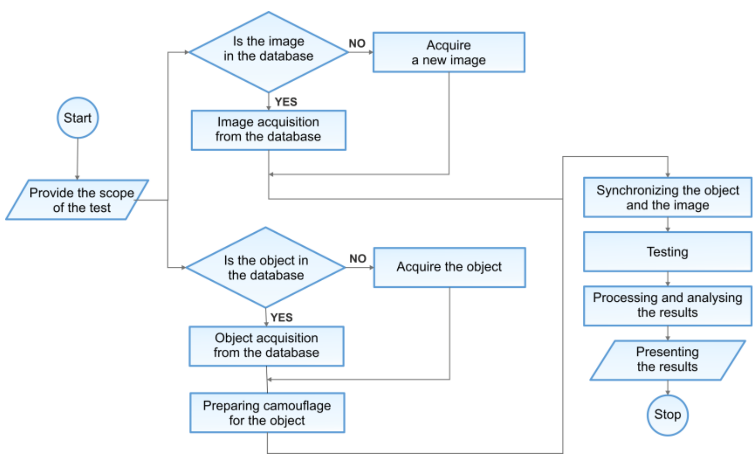

Fig. 8. Algorithmic visualisation of the method

Test studies were carried out to verify and validate the concept.

From the image database, an image taken with a Canon EOS 5D camera was downloaded and it was characterised by the following parameters: location – Central Europe; lowlands; latitude = 50.4N, longitude = 21.8E; scenery – deciduous forest; distance to the object observed – 500 m, season – summer; azimuth – 325°, weather condition – no wind, cloud cover – 1/8 octane; resolution 5616 × 3744 px, colour space – Adobe RGB; tonal resolution – 8 bit/channel; white balance – corrected to conform with white standard; lens focal length – 50 mm; matrix size –

36×24 mm; exposure – ISO100 sensitivity; aperture 1/9; time 1/400s. For these parameters, the actual image height of H = 0.24·500/0.50 = 240 m was determined.

A camouflage pattern was designed and applied onto the Leopard 2A4 MBT (Fig. 5a-c). The object was visually synchronized with the image. Vehicle dimensions (length, height) were obtained from the tank manufacturer – Kraussss-Maffei Wegmann GmbH & Co [12] and were used to adjust the scale of the object and the image. Colour synchronization was ensured via the use of the same colour space – Adobe RGB – and the use of a perceptually homogeneous CIE L*a*b* colour model. Based on the geographic and weather information as well as the imaging date, chiaroscuro for the object was generated, as shown in Fig. 5d.

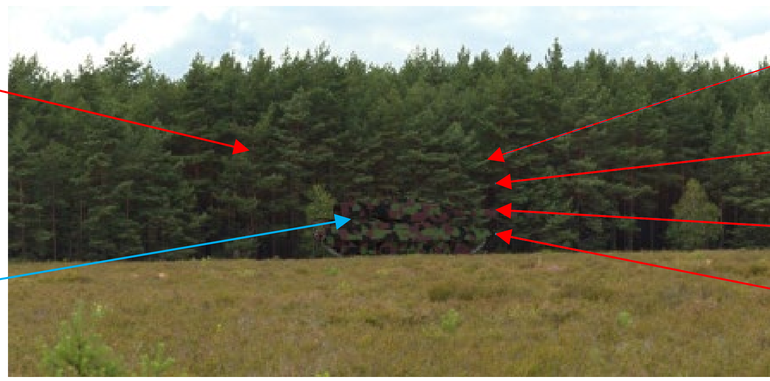

Fig. 9. Synchronisation of the sample and image

The projector was colour-calibrated. Using formula (2), the distance of the observer position from the screen L_e = 1.6 500/240 = 3.3 m was determined as equivalent to the distance to the object (500 m). Due to the perceptive capabilities of the human eye (minimum viewing angle, sharp viewing angle) and the parameters of the image projected by the projector (resolution 1200 × 800 px and dimensions of 3.6 × 2.4 m), the distance Le' = 6.6 m was corrected to avoid perception of individual pixels. A series of scale factors for image d was calculated for the corrected distance Le' and for the corresponding simulated distances to the object (d = ×1 → L = 1000 m, ×1.1 → 900 m, ×1.3 → 800 m, ×1.4 → 700 m, ×1.7 → 600 m, ×2 → 500m).

To properly simulate the real conditions, a group of observers should be furnished with a set of images presenting the equipment to be identified corresponding to different distances from individual distances. Independently, each observer should be presented with an image for max. 2 minutes, starting from the image taken at the greatest distance to the object (1000 m) to the shortest one (or until the object has been identified). Conditions for object visibility, namely *no detection*, *recognition*, *identification* will be recorded during tests for each observer. The measurements should include observations for a control sample, i.e. images which do not include the investigated/observed equipment.

Fig. 10. Examples of images for differing distances of the object to the observer

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Summary

In the case of designing new dedicated camouflages by testing many variants, one could expect a result in the form of selection of an improved pattern, better suited to the selected background or the ability to check its versatility against the backdrop of many sceneries.

This concept is designed to be used for various types of objects, i.e. uniforms, vehicles, camouflage nets or mobile camouflage, and for various research methods, such as unaided eye, camera on a flying platform, binoculars, night vision devices and near infrared, which makes it a universal solution.

In addition, the implementation of this concept, due to the already existing image base, would not carry with it any additional initial costs, whereas open architecture and the possibility of supplementing the database with new images would enable the extension of the concept's functionality with new environments, seasons, observation methods, etc.

The implementation of the developed concept for the virtual method could contribute to the reduction of time and costs of the camouflaging efficiency assessment tests, which are a part of standard procedure used for a number of newly-delivered products to be in service with the armed forces.

References

[1] NATO RTO, Guidelines for Camouflage Assessment Using Observers (RTO-AG-SCI-095), NATO RTO (2006)

[2] M. Dojlitko, Teoria dekonstrukcji komunikatu wizualnego. Narzędzia projektowania kamuflażu militarnego, Gdańsk, ASP w Gdańsku, 2015.

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

[4] G. Thayer, A. Thayer, Concealing-Coloration in the Animal Kingdom, The Macmilan Co, New York, 1909.

[5] The Naval Historical Center, https://history.navy.mil/our-collections/photography/numerical-list-of-images/nhhc-series/nh-series/NH-53000/NH-53548.html, (accessed on 2019.11.13).

[6] P. Francuz, Imagia, W kierunku neurokognitywnej teorii obrazu, Lublin, Wyd. KUL, 2013.

[7] D. M. Dacey, Parallel pathways for spectral coding in primate retina. Annual Review of Neuroscience 23 (2000) 743-775. https://doi.org/10.1146/annurev.neuro.23.1.743

[8] M. Wykowska, Ergonomia, Kraków, AGH, 1994.

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

[10] Turbosquid, https://www.turbosquid.com/pl/3d-models/polish-leopard-2a4---3d-c4d/619862, (accessed on 2019.11.13).

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

[12] Kraussss-Maffei Wegmann GmbH & Co, https://www.kmweg.com/home/tracked-vehicles/main-battle-tanks/leopard-2-a4/product-specification.html, (accessed on 2019.11.13)