Applying of Experiences from NATO SCI Collaboration into the Field of Military Professionals Education

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ABSTRACT

The Department of Weapons and Ammunition is one of the departments of the Faculty of Military Technologies of the University of Defence in Brno, Czech Republic. The department's technical specialization focuses on the following branches of science: ballistics, barrel-type weapons, ammunition, and optoelectronic armament systems. Technical specialization in the field of optoelectronic armament systems is closely focused on the area of design, analyses and valuation of effectivity of the optical devices in the weapon systems, its constructional parts and the equipment. Moreover, the research interest of group of optoelectronic armament deals with the enhancement of theory of both design and utilization of surveillance and target acquisition systems, aiming devices up to Fire Control Systems. Camouflage, as an art of target blending into its background, is an effort that significantly decreases the effectivity of systems of surveillance and target acquisition. Thus, the newest knowledge in the field of camouflage techniques influences the development of surveillance and target acquisition systems and on the other hand, the development in surveillance and target acquisition forces the alternation of camouflage techniques. The collaboration of DoWA staff with NATO SCI groups allows us to implement not only the theoretical aspects into the education process but also the real experience and knowledge from field campaigns. The papers deals with introduction of DoWA and the group of optoelectronic armament systems especially. It will also be presented the way of explanation of camouflage and surveillance system relationship and finally the examples of scientific research results.

1.0 INTRODUCTION OF DEPARTMENTS OF WEAPON AND AMMUNITION

The Department of Weapons and Ammunition (DoWA) is one of the departments of the Faculty of Military Technologies of the University of Defence in Brno, Czech Republic. Educational content of the department is focused on:

- ballistics, explosives, initiators,
- design and usage of ammunition,
- design and usage small arms,
- design and usage of artillery weapons,
- design and usage of military optical devices and fire control systems,
- Theory and practice of logistic support of the army with stress on the armament

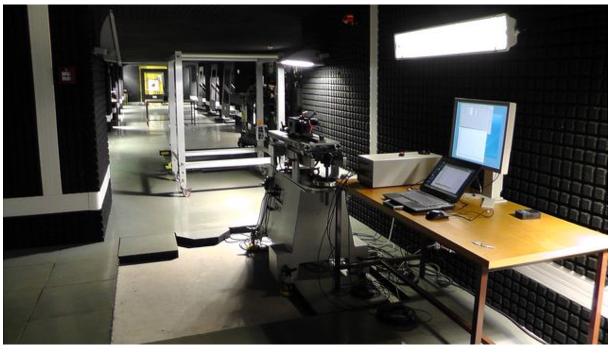
The department provides the full-time and part-time graduate study in Bachelor's (Bc.) and Master's (Eng.) study programs and the post-graduate study in a Doctoral (Ph.D.) study program as follow:

- Long-cycle Master's study: full-time, 5 years, Czech study language, for military students
- Bachelor's study: full-time, 3 years, Czech and English study language, for civilian students
- Master's study: full- and part-time, 2 years, Czech study language, for military and civilian students
- Doctoral study: full- and part-time, 3 years, Czech and English study language, for military and civilian students

- Special courses for the military, police and civilian technical personnel

The scientific and expert activities of the department are aimed into the fields of:
- design and assessment of the small arms,
- interior, exterior and terminal ballistics of small arms and artillery ammunition,
- design and assessment of ammunition,
- design and assessment of military electronic and optical devices,
- usage, maintenance and diagnosis of the weapon systems.

The laboratory equipment (see Fig. 1) of the department corresponds to its specialization. Special measurements with weapons, ammunition and optical devices can be done in:
- laboratory for testing the automatic weapons,
- laboratory for testing the small arms ammunition and ballistic testing,
- laboratory for testing the military optical devices and the hyper-spectral testing,
- laboratory for testing the weapon operators,
- laboratory for testing the passive tracking systems.

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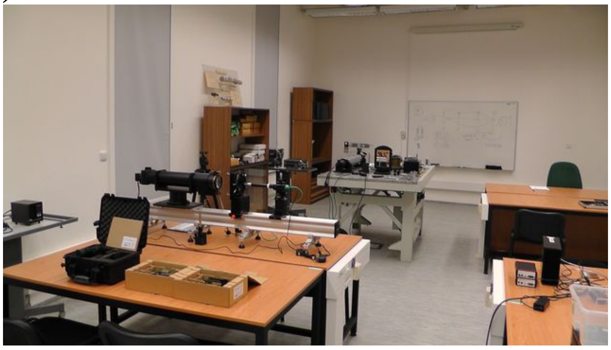


c)

Figure 1: Demonstration of laboratories of the department; a) Ballistic laboratory, b) Laboratory for testing the small arms ammunition, c) Optical laboratory.

2.0 CAMOUFLAGE, SURVEILLANCE DEVICES AND WEAPON SYSTEM

The weapon system (WS) is defined as a combination of one or more weapons with all related equipment, materials, services, personnel, and means of delivery and deployment (if applicable) required for self-sufficiency [1]. Contemporary weapons (or weapons systems) are generally a sum of means of straight destruction (bullets, poisonous substances, etc.) with means of transport (firing, launching, dropping) of means of straight destruction (such as rocket, aircraft, drain, gun), as well as surveillance and aiming devices, pointing devices, etc [2].

The process of controlling the fire from the weapon consists of at least three main phases. Firstly, it is to acquire the target and to collect all of the appropriate input data about the target, fire conditions and weapon itself. Secondly to compute in any way both the elevation and azimuth components of barrel orientation prerequisite to reach the projectile to the target. Thirdly, to apply said components in the mechanisms of the barrel control system to aim the barrel axis correctly. In the case of general Fire Control System [3], these three phases can principally be associated with Acquisition and Tracking Subsystems (ATS), Firing Data Computing Subsystems (FDCS) and Weapon Pointing Subsystems (WPS) as illustrated in the flow diagram in Fig. 2.

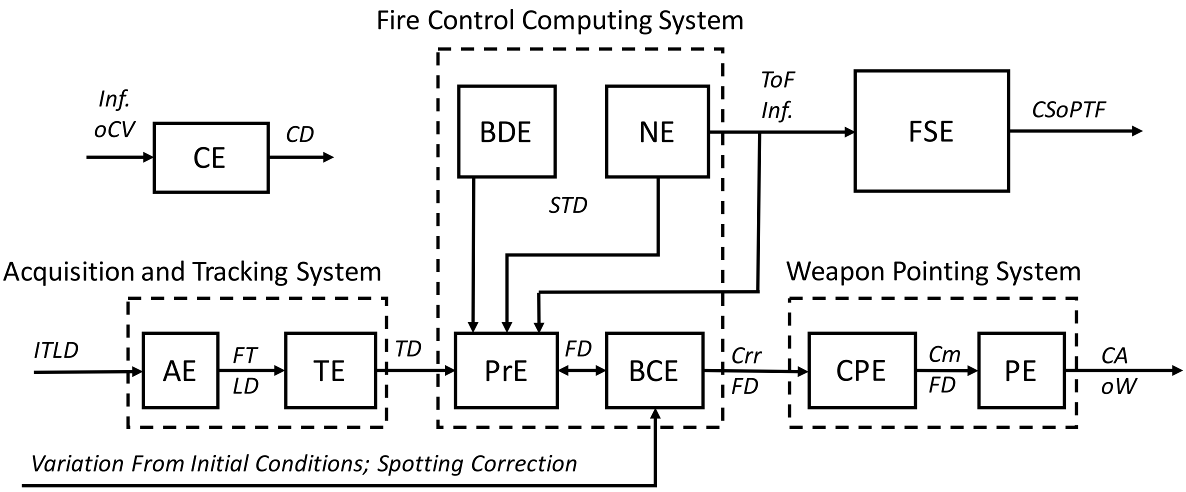


Figure 2: Fire Control Process [3].

The Acquisition and Tracking Subsystem, as a first part of FCS, takes crucial role in the FCS workflow due to its initial position in the system. The necessity of this fire control phase is met by the elements of acquisition (AE) and tracking (TE). Through the acquisition elements the procedures of observation, surveillance, target acquisition, and reconnaissance are provided. A plenty of different systems and physical principles can be used to acquire the target, however it is primarily associated with optical devices.

It was introduced the role of optical devices in the weapon system. The optical device can be defined as a device that operates the optical radiation. Since the OPTICS or PHOTONICS respectively is the science that deals with generation, propagation and detection of optical radiation, the optical devices are associated with mentioned phenomena. For the purpose of this paper, the optical device is understood as a device that generate, manipulate or detect optical radiation transmitting certain information.

The generic optical device operation and optical radiation propagation is illustrated in flow chart in Fig. 3. The actual configuration of the radiation path depends on the device category and intention. Let assume the thermal imaging camera as a general example. The optical radiation path and optical device operation can be described as follow. The radiation of external source Φs propagates through the atmosphere and is affected by its properties. This radiation ΦsA irradiate the target, background and camouflage items. The reflected radiation ΦsAT+ ΦsAB+ ΦsAC together with heat radiation ΦHT+ ΦHB+ ΦHC propagate through the atmosphere towards the optical device. Thus, the optical system of optical device collects the mix of radiation ΦsAS+ ΦsATA+ ΦsABA+ ΦsACA + ΦHA+ ΦHT+ ΦHB+ ΦHC, where ΦsAS and ΦHA is radiation of external source scattered in the atmosphere and atmosphere essential heat radiation respectively. The optical system forms the image. The image is grabbed, processed and displayed to the human.

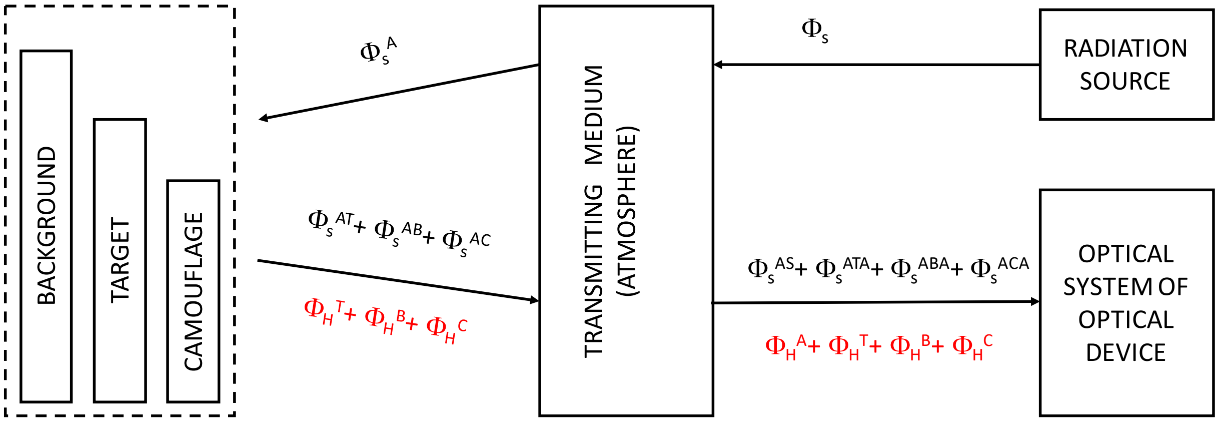


Figure 3: General optical device operation and optical radiation propagation.

The link between camouflage and surveillance is obvious as it is indicated in Fig. 4. Camouflage methods affect the surveillance instruments and vice versa, surveillance instruments affect the camouflage techniques. Constantly and mutually, the development in one area results in pressure for development in the other area.

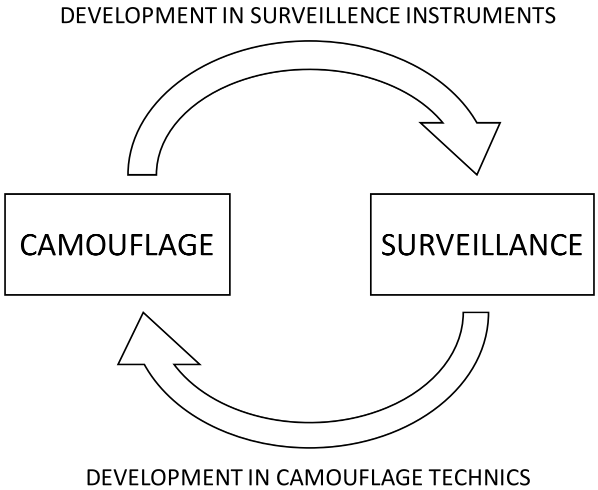


Figure 4: The link between camouflage and surveillance.

The camouflage is defined as the use of natural or artificial material on personnel, objects, or tactical positions with the aim of confusing, misleading, or evading the enemy [4]. The camouflage is in fact very complex problem involving all areas and activities of military troops. The role of camouflage in the paths of optical signal is illustrated in Fig. 3. The optical radiation emitting from the target (inherent or reflected) is mixed with signal emitting from the background and just from the camouflage means. Thus, the camouflage in optical region can be understood as suppression (or replacement) of all target characteristics transmitted by electromagnetic waves in optical bandwidth and detectable by optical surveillance systems. The information that is receiving by optical devices is transmitted in the form of variation of certain property of optical radiation. The properties of optical radiation are: 1. Spatial characteristics (Size, Spatial Frequency, Shape, outline, shape symmetry, …), 2. Spectral characteristics (Colors, Remission Spectra, Thermal radiation spectrum), 3. Power characteristics (Photometric quantities, Radiometric quantities), 4. Polarization. To be the camouflage effective in optical bandwidth, it must act on at least one of the characteristics transmitted by the optical radiation. In the case of optical surveillance, we try to obtain all relevant information from the optical signal. On the other hand, in the case of optical camouflage, we try to remove or hide the target information from the optical signal.

The above-mentioned mutual relationship between surveillance and camouflage defines significant requirements for design of optical devices, for design of methods of optical signal processing and for design of camouflage means. To accomplish these three task it is necessary, besides the others, 1. to know the properties and characteristics of natural background, 2. to be able to verify the physical properties of camouflage means and 3. to verify the effectivity of camouflage means. In addressing all these challenges, we have been inspired by our collaboration with NATO CSO SCI-295 Task Group 295 "Development of Methods for Measurements and Evaluation of Natural Background EO Signatures".

3.0 THE REFLECTION OF SCO-295 COLLABORATION IN EDUCATIONAL PROCESS

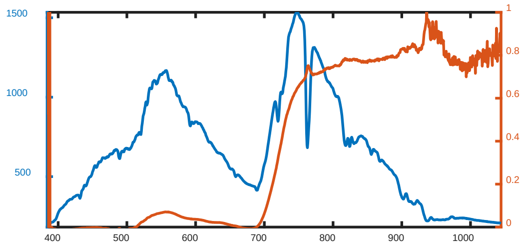
The experience and knowledge gained in collaboration with SCO-295 are reflected in the preparation of students of (DoWA) in various forms. The primary impact is on the teaching in subjects of Optical Devices of Weapons and Fire Control Systems. The subject are intended for bachelor and magister studies respectively. Both the subjects are focused on obtaining of knowledge and skills in the area of military optical and opto-electronical devices, sights and Fire Control Systems, their design, functions and utilization. Nonetheless, most significantly, the SCO-295 collaboration is reflected in independent scientific and creative work of WoAD and thus in the topics of students' final theses. It is presented in the following subparagraphs, the results of our work, which coincide with the focus of SCO-295.

3.1 Using of hyperspectral imaging for determination of properties and characteristics of natural background

The hyperspectral (HS) camera, in other words imaging spectrometer, is the modern electro-optical device capable of acquisition of complex target data. The HS imaging is the vertex of technology pyramid, the fundament of which is formed by spectrometry, radiometry and imaging. Any of named technology collects some important information of light. Spectrometry obtains the variability of light as a function of wavelength, radiometry obtains the information about the energetic amount of light and the imaging obtains the spatial distribution of light. Thus, only one measurement device can take the richest optical information from area of interest (compare with previous chapter). While the ordinary monochromatic or color camera records the only spatial distribution of light (color respectively) in the image plane, the hyperspectral camera, on the other hand, records the full information about spatial distribution of spectral and energetic features of light in the image plane.

As the use of multispectral and hyperspectral means in military surveillance and target acquisition increases, the threat for camouflaged objects is also growing. One of the possible steps to improve the quality of camouflage means is to increase our knowledge of the spectral properties of the natural background. The articles Spectral Characterization of Natural Background in Virtue of Reconnaissance Possibilities [5], NATO hyperspectral measurement of natural background [6], Hyperspectral discrimination of camouflaged target [7] and Collecting information for spectral boundaries determination [8] presents the possible methods for evaluating the background spectral characteristics. The announced methods are presented on the data of a field campaigns. Moreover, based on the experiment results the relevant parameters of the multispectral reconnaissance means could be determined.

There are the examples of HS data processing in Fig. 5 as it was presented in [5]. Figure 5a represents the conversion of pixel vector of tree canopy into the reflectance. The presented data are valid for the VNIR HS camera Specim V10E. The variation of HS data during the day, as it was determined in [5] are presented in Fig. 5b. In this case, the data are valid for the HS camera ISOB Eagle.



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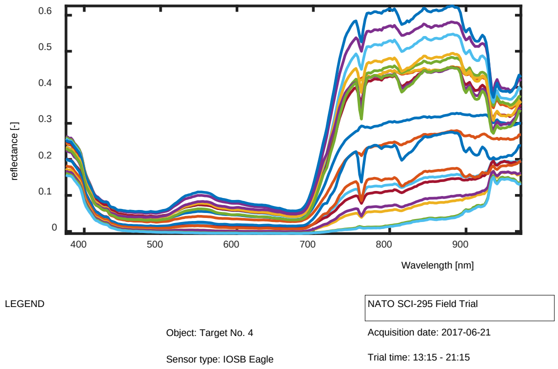


b)

Figure 5: The results of determination of spectral characterization of natural background [5].

Another example of HS data processing is presented in Fig. 6. The mentioned figures were presented in [7]. There you can see result of processing HS data of camouflaged objects in the winter conditions. The RGB visualization of HS image and contains two persons camouflaged on the background of snow cover is illustrated in Fig 6a. The result of processed data of the same datacube is presented in Fig. 6B. There you can recognize separated camouflaged objects. The separation of the camouflaged objects was processed using the spectral information only.

a)

b)

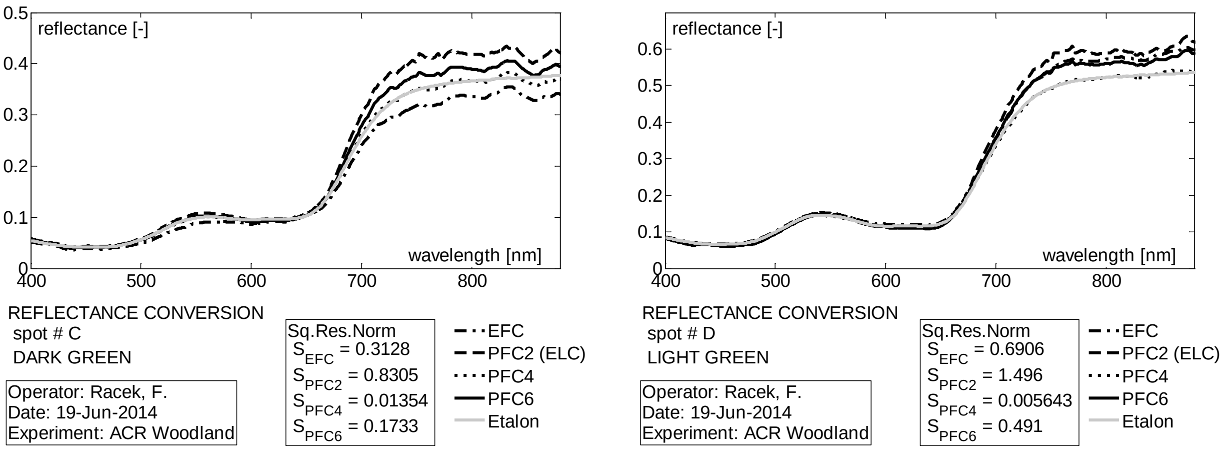
Figure 6: The separation of the camouflaged objects in winter conditions [7].

Due to rich spectral information contained in HS datacube, the HS data processing is aimed to the processing of spectral characteristics of the objects inside the imagined scenery. On the contrary, the spatial pattern recognition techniques common in multispectral imaging are in HS imaging assumed as a subsidiary. Thus, the HS data processing is focused on the recognition of mixed spectra (mixed pixel) or the recognition of object in the scenery the dimension of which is under the spatial resolution of HS system (subpixel). Anomaly detection is a particular kind of HS image processing in the case that no prior information about target is known and no specific target is seeking. The key task of anomaly detection is finding the objects that are anomalous comparing to its background. Extensionally, it is looked for the pixels the spectrum of which is significantly different. In the following articles, there a presented our abilities in methods of datacube processing: Ability of Utilization of PCA in Hyperspectral Anomaly Detection [9], Spectrally Based Method of Target Detection in Acquisition System of General Fire Control System [10], Hyperspectral Data Conversion in the Case of Military Surveillance [11], Spectral Angle Mapper as a Tool for Matching the Spectra in Hyperspectral Processing [12].

3.2 Using of hyperspectral imaging for measurement of physical properties of camouflage surfaces

According to [13] "The typical measure of effectiveness for a camouflage system is target detectability in a tactical situation. There are a number of technical parameters describing the physical characteristics of a camouflage material, such as color values, transmission, radar absorption, etc. These parameters can be measured in a laboratory using standardized procedures and apparatus and can provide some indication of field performance". The properties of hyperspectral imaging (as described in previous chapter) can be used not only for the purposes of optical surveillance, but can also be advantageously used for testing the properties of camouflage surfaces. The hyperspectral imaging can take significant role in testing the physical characteristics of camouflage materials. The issue of using hyperspectral imaging for testing the camouflage surfaces is dealt with in the three presented articles in this chapter.

The paper Utilization of hyperspectral camera for determination of camouflage surfaces spectral characteristics homogeneity [14] deals with description of newly developing method of Hyperspectral camera utilization for determination of camouflage surfaces spectral characteristics homogeneity. The color patterns of camouflage surfaces are usually checked pointwise. It is assumed subsequently that the spectral characteristics of the pattern are the same for whole area of camouflage surface. The essential properties of hyperspectral camera allow to determine the level of spectral qualities homogeneity of the surface. Although the respective snapping of hyperspectral image is easy, the evaluation of HS datacube features specific problems connected with homogeneity of illuminance, optical system aberrations, transformation to reflectance and spectral unmixing. All the measurement aspects have to be taken into account to correctly determine the homogeneity of camouflage surfaces spectral characteristics It was also discussed in the paper the best way of HS datacube conversion into the reflectance. The four possible methods were introduced and analysed. In the Fig. 7, there is presented comparison of object reflectance determination. The objects of interests were the two color spot of the camouflage pattern. The result of conversion of dark green spot is illustrated in Fig. 7a and the conversion of light green spot in Fig. 7b.



(a) (b)

Figure 7: The comparison of converted spectral reflectance curves [14].

The next paper Selected issues connected with determination of requirements of spectral properties of camouflage patterns [15] builds on the previous paper and deals with the possibilities of evaluation of spectral curves. Traditionally spectral reflectance of the material is measured and compared with permitted spectral reflectance boundaries. The boundaries are limited by upper and lower curve of spectral reflectance. The boundaries for unique color has to fulfil the operational requirements as a versatility of utilization through the all year seasons, day and weather condition on one hand and chromatic and spectral matching with background as well as the manufacturability on the other hand. The interval between the boundaries suffers with ambivalent feature. Camouflage pattern producer would be happy to see it much wider, but blending effect into its particular background could be better with narrower tolerance limits. From the point of view of long time user of camouflage pattern battledress, there seems to be another ambivalent feature. Width of the tolerance zone reflecting natural dispersion of spectral reflectance values allows the significant distortions of shape of the spectral curve inside the given boundaries.

The third paper Pixelated Camouflage Patterns from the Perspective of Hyperspectral Imaging [16] deals with the specific influence of digitized camouflage on a special camera. Pixelated camouflage patterns fulfil the role of both principles the matching and the disrupting that are exploited for blending the target into the background. It means that pixelated pattern should respect natural background in spectral and spatial characteristics embodied in micro and macro patterns. The HS imaging plays the similar, however the reverse role in the field of reconnaissance systems. The HS camera fundamentally records and extracts both the spectral and spatial information belonging to the recorded scenery. Therefore, the article deals with problems of hyperspectral (HS) imaging and subsequent processing of HS images of pixelated camouflage patterns which are among others characterized by their specific spatial frequency heterogeneity.

3.3 Camouflage effectivity testing

As mentioned in previous chapter there is a mutual connection between camouflage and surveillance instruments. Therefore, the method and techniques of camouflage are based on how the optical radiation is sensing and subsequently how the information taken from optical radiation is evaluated. In accordance with generic optical device scheme in Fig. 3, the actual arrangement of the optical design depends on detected characteristic of optical radiation, used spectral region and the way of signal processing. The most common arrangement of optical device utilization in armed forces are: naked eye observation and human observation through the telescope or NVG. For all the three way it is common that the color or monochromatic image formed by the optical device is processed by the human.

Thus, the most common way of processing an image is the human sensing, i.e. a human observes an image formed by an optical device and evaluates the symptoms if there is a camouflaged object or not. In this case, the parameters of the optical devices as well as the physiological properties of human eye affect acquisition performance. However, the most influence is the way the observer is detecting a target against a background.

The measurement of camouflage effectiveness is a task that can be divided into two fundamental steps. Firstly, it is the measurement of physical characteristics as it was presented in previous chapter. The second task is measurement of subjective detectability. The task of subjective detectability as a measure of the camouflage effectiveness can be done as field trial or as a laboratory measurement. In the case of field trial, number of observers usually solve an acquisition task under the real condition and their results are statistically processed. In the laboratory measurement, so-called photosimulations test, the conditions of field trial are recorded in the form of images. The images are, under the specific condition, displayed to the number of observers. The observers solve the modified acquisition task and their results are statistically processed too.

Many common features can be found between the photosimulation test and the measurements of target acquisition performance (TAP) metrics. Similar to the camouflage effectiveness measurement, the target acquisition performance characterization is joined with field performance and a laboratory sensor testing. During the laboratory TAP performance, the humans observe the set artificial images of test patterns. The observers judges the images and from their response the TAP metrics are determined. I tried to use the experiences, methods, and metrics developed for evaluation of TAP and apply them for the evaluation of camouflage efficiency in following two papers.

The new approach to evaluating photosimulation test results is embodied in the paper Evaluation of validity of observer test for testing of camouflage patterns [17]. Physical characteristics of camouflage patterns such as color or remission spectra can be tested and measured by objective methods. In the vast majority of use of camouflage pattern, the human (obscure person) will recognize the camouflaged object. Therefore, the quality of the camouflage pattern ultimately determines how a person in a given environment perceives the camouflage pattern. Human perception is very subjective, and its assessment cannot be measured by simple physical methods. Therefore, we process the observer’s visual performance when searching for camouflaged objects. It must always be based on the statistical processing of information on perceived quality of camouflage by individual observers. One of the methods for assessing the quality of camouflage surfaces is so called observer test. The observer test is a simple visual test in which a number of viewers observe a series of images of different scenes containing camouflaged object. The time taken to find the camouflaged object is measured. Depending on the time, it takes to find the camouflaged object, the quality of the camouflage pattern is judged. The time required to find a camouflaged object depends, among other, on the arrangement of the scene, the conditions of the observer test, how the observer interacts with the test interface, the observer's properties and last but not least the camouflage pattern quality. The time taken to find a camouflaged object by a particular observer in a particular frame must be assumed as a random variable because it depends on a large number of independent factors. The rated quality of the camouflage pattern is only one of these factors. Among the others, it was aim of the experiment we performed to evaluate the statistical behavior of the random variable to be able to describe the behavior of it by a suitable type of distribution.

Another step in new approach to evaluating photosimulation test results was the application of TAP metrics and is described in paper Target Acquisition Performance as a Criterion of Camouflage Pattern Effectiveness [18]. It is presented in the text the results and analysis of a photosimulation digital camouflage assessment trial. The amount of human observers were employed to get a robust statistical data. We have conducted a study to investigate possible improvements in camouflage patterns effectiveness determination. The aim was to prepare a study of potential of target acquisition performance as a figure of merit of camouflage pattern effectiveness.

The example of result of the analysis of the unique camouflage pattern in all sceneries of unique photosimulation test are presented in Fig. 8. There is presented the result of testing if the data comes from the population that can be described by Weibull or Rayleigh distribution.

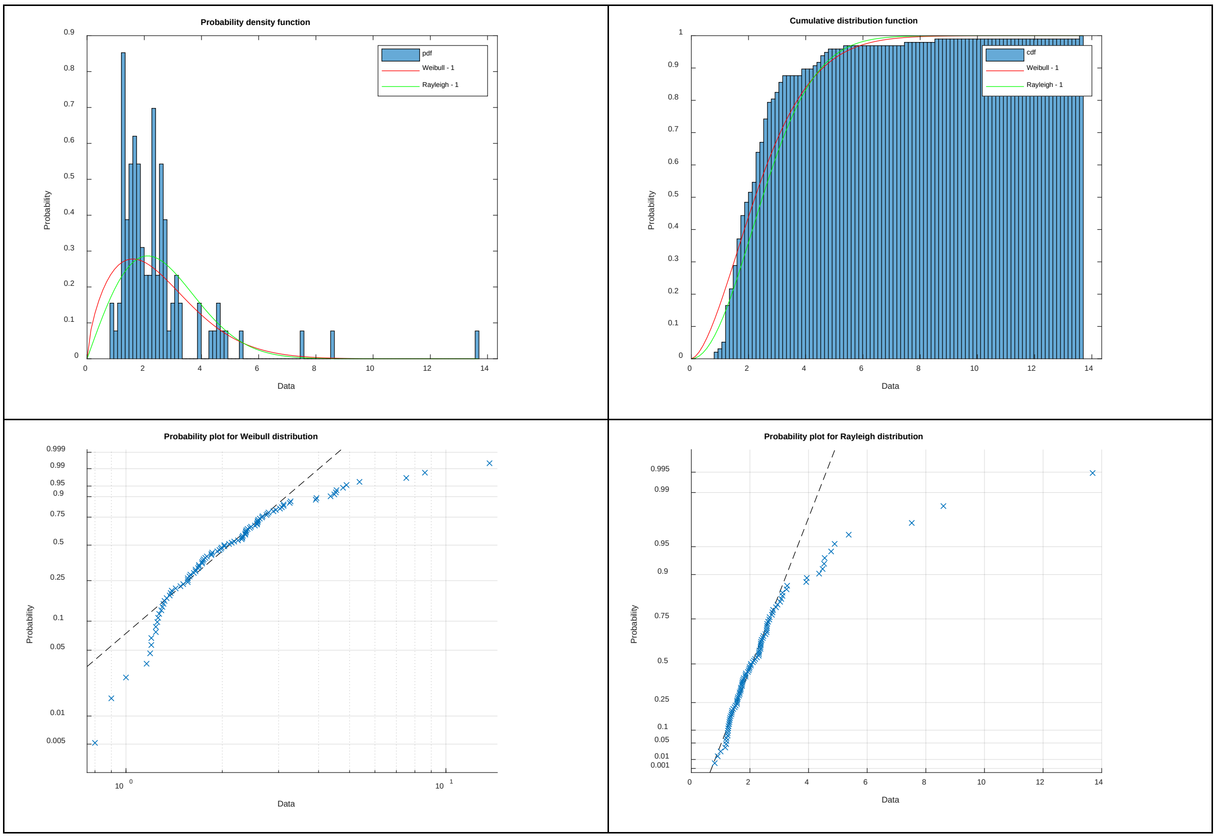


Figure 8: The example of results of goodness-of-fit test for Rayleigh and Weibull distribution [17].

4.0 CONCLUSION

The relationship between surveillance and camouflage defines significant requirements for design of optical devices, for design of methods of optical signal processing and for design of camouflage means. To accomplish these three task it is necessary, besides the others, 1. to know the properties and characteristics of natural background, 2. to be able to verify the physical properties of camouflage means and 3. to verify the effectivity of camouflage means. In addressing all these challenges, we have been inspired by our collaboration with NATO CSO SCI-295 Task Group 295 "Development of Methods for Measurements and Evaluation of Natural Background EO Signatures".

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REFERENCES

[1] U. D. o. Defence, „DOD dictionary of Military and Associated Terms," November 2018. [Online]. Available: https://www.jcs.mil/Portals/36/Documents/Doctrine/pubs/dictionary.pdf.

[2] V. ČECH, „Research and development of model of evaluation of weapon and weapon effectiveness [in Czech]," Akademie o.p.s., Brno, 2002.

[3] US Army Armament Research, Development, and Engineering Center, Fire Control Systems - General, 5203 Leesburg Pike, Suite 1403, Falls Church, VA: Defense Quality and Standardization Office, 1996.

[4] U. D. o. Defence, Department of Defense Dictionary of Military and Associated Terms, US Department of Defense. The Secretary of Defence, 2004

[5] RACEK, František; BALÁŽ, Teodor. Spectral Characterization of Natural Background in Virtue of Reconnaissance Possibilities. In: International Conference on Military Technologies 2019 (ICMT'19). Brno: University of Defence, Brno, 2019.

[6] BÁRTA, Vojtěch; RACEK, František; KREJČÍ, Jaroslav. NATO hyperspectral measurement of natural background. In: *TARGET AND BACKGROUND SIGNATURES IV*. Bellingham, Washington USA: Society of Photo-Optical Instrumentation Engineers (SPIE), 2018, p. nestránkováno. ISSN 0277-786X. ISBN 978-1-5106-2172-5.

[7] BÁRTA, Vojtěch; RACEK, František. Hyperspectral discrimination of camouflaged target. In: *Target and Background Signatures III*. BELLINGHAM, WA 98227-0010 USA: SPIE-INT SOC OPTICAL ENGINEERING, 2017, p. "1043207-1"-"1043207-9". ISSN 0277-786X. ISBN 978-1-5106-1328-7.

[8] BÁRTA, Vojtěch; HANUŠ, Jan. Collecting information for spectral boundaries determination. In: Target and Background Signatures IV. Bellingham, Washington USA: SPIE-INT SOC OPTICAL ENGINEERING, 2018, p. nestránkováno. ISSN 0277-786X. ISBN 978-1-5106-2172-5.

[9] RACEK, František; BALÁŽ, Teodor; MELŠA, Pavel. Ability of Utilization of PCA in Hyperspectral Anomaly Detection. In: *International Conference on Military Technologies 2015 (ICMT'15)*. Brno: University of Defence, Brno, 2015, p. 19-22. ISBN 978-80-7231-976-3.

[10] RACEK, František; BÁRTA, Vojtěch. Spectrally Based Method of Target Detection in Acquisition System of General Fire Control System. In: *Conference Proceedings of ICMT'17*. Piscataway, NJ 08854-4141 USA: Institute of Electrical and Electronics Engineers Inc., 2017, p. 22-26. ISBN 978-1-5386-1988-9.

[11] RACEK, František; BALÁŽ, Teodor; MELŠA, Pavel. Hyperspectral Data Conversion in the Case of Military Surveillance. *Advances in Military Technology*, 2015, vol. 10, no. 1, p. 5-13. ISSN 1802-2308.

[12] RACEK, František; BALÁŽ, Teodor. Spectral Angle Mapper as a Tool for Matching the Spectra in Hyperspectral Processing. *Advances in Military Technology*, 2012, vol. 7, no. 2/2012, p. 65-76. ISSN 1802-2308.

[13] J. PEAK, L. HEPFINGER, R. BALMA, G. CHRISTOPHER, J. FLEURIET, T. HONKE, G. HUEBNER, E. MAUER, P. DOTOLI, P. RONCONI a P. JACOBS, „Guidelines for Camouflage Assessment Using Observers," NATO RESEARCH AND TECHNOLOGY ORGANISATION,

Neuilly-sur-Seine Cedex, 2006

[14] RACEK, František; BALÁŽ, Teodor; JOBÁNEK, Adam. Utilization of hyperspectral camera for determination of camouflage surfaces spectral characteristics homogeneity. In: *SPIE Security + Defence*. Toulouse, France: SPIE Press, 2015, p. "96530K-1"-"96530K-13". ISSN 0277-786X. ISBN 9781628418637.

[15] RACEK, František; BALÁŽ, Teodor; KREJČÍ, Jaroslav; JOBÁNEK, Adam. Selected issues connected with determination of requirements of spectral properties of camouflage patterns. In: *Target and Background Signatures III*. BELLINGHAM, WA 98227-0010 USA: SPIE-INT SOC OPTICAL ENGINEERING, 2017, p. "1043205-1"-"1043205-12". ISSN 0277-786X. ISBN 978-1-5106-1328-7.

[16] RACEK, František; JOBÁNEK, Adam; BALÁŽ, Teodor; KREJČÍ, Jaroslav. Pixelated Camouflage Patterns from the Perspective of Hyperspectral Imaging. In: *Target and Background Signatures II*. Edinburgh: SPIE, 2016, p. nestránkováno. ISSN 0277-786X. ISBN 978-151060398-1.

[17] RACEK, František; BALÁŽ, Teodor; KREJČÍ, Jaroslav; JOBÁNEK, Adam. Evaluation of validity of observer test for testing of camouflage patterns. In: *Target and Background Signatures IV*. Bellingham, Washington, USA: Society of Photo-Optical Instrumentation Engineers (SPIE), 2018, p. nestránkováno. ISSN 0277-786X. ISBN 978-1-5106-2172-5.

[18] RACEK, František; KREJČÍ, Jaroslav. Target Acquisition Performance as a Criterion of Camouflage Pattern Effectiveness. In: Conference Proceedings of ICMT'19. Piscataway, NJ 08854-4141 USA: Institute of Electrical and Electronics Engineers Inc., 2019.