УДК 623.4.05; 004.932.72 DOI: https://doi.org/10.33577/2312-4458.28.2023.69-76

D. Khaustov, O. Kyrychuk, T. Stakh, Ya. Khaustov, R. Sidor, O. Burashnikov, Ye. Ryzhov, Yu. Nastishin

Hetman Petro Sahaidachnyi National Army Academy, Lviv

Article history: Received 21 March 2023; Revised 24 March 2023; Accepted 31 March 2023

TARGET VISIBILITY INDEX

Quantitative description of the quality of images from the military sight-seeing systems, particularly those of armored vehicles, implies specific approaches different from those used in traditional image processing for civilian needs. Our analysis of the literature shows that there are several disadvantages in the definitions of the quantitative image quality indices, which makes them inapplicable for the characterization of targets in images from military sight-seeing systems. First, quantitative indices describing the quality of images introduced for civilian applications and techniques for their measurements are not target-oriented. In most cases, image quality indices available in the literature characterize the image as a whole but turn out to be irrelevant to the visibility and conspicuity of a target. High image quality indices do not guarantee high visibility and conspicuity of a target. Contrarily, frequently high contrast and thereby visibility of a target is accompanied by abnormal (enormously high or low) lighting of the background, target, or both, which enhances the visibility and conspicuity of the target but results in low-quality indices of the image as a whole. Second, expressions for the contrast, visibility, and conspicuity of a target available in the literature are not symmetric with respect to zero and some of them are singular functions. We claim that an image quality index describing the target visibility should satisfy, at least, the following requirements. First, the notion of the threshold local contrast, still (or no longer) resolved by human eyes, must be involved in the definition of visibility. Second, the visibility index should not be a singular function. Third, visibility is a notion strongly related to the neuronal response of the human brain and, thus, should be in the form of an activation function. Forth, the target visibility index should be of the probability character. Fifth, the visibility index should be target-oriented. In this paper, we propose an expression defining the target visibility index which satisfies all five requirements listed above and develop a technique for its measurement based on the measurements of brightness profile along a line and calculation of the local contrast of the target. The measurements of the target visibility index are illustrated for the partial (visible and infrared) images and for images fused by algorithms of different target-oriented image fusion methods.

Ключові слова: *local contrast, visibility, conspicuity, saliency of a target, target visibility index, target-oriented image fusion.*

Introduction

Nowadays, advanced armored vehicles are equipped with target sight-seeing systems capable of registration of the target-background situation (TBS) in digital electronic image format. With the TBS recorded in computer memory and monitored on a notebook display, the object detection procedure became a subject of Computer Vision, a branch of Computer Science rapidly developing in response to strong demands in numerous branches of human activity from simple needs such as video surveillance for security guarding purposes and road monitoring to highly intellectual applications in industry, medicine, military, space, and other sciences. In application to military needs, object detection is embraced by a more general term target data acquisition (TDA).

The TDA includes search, detection, recognition, and identification of a target. The terms visibility, conspicuity, and saliency of a target are keywords in the characterization of the TDA processes. In the literature, one finds several different definitions of these terms from purely qualitative characteristics to quantitative indices supplemented by specially designed methods for their measurement. For example, in [1] the term visibility is defined as: "the quality, state or degree of being capable of being seen", while the term conspicuity is defined as: "how well the detail stands out from the background". In many cases, the terms visibility and conspicuity are used interchangeably. Our analysis of the literature shows that the definitions of these key terms highly depend on the aim of their application. In this paper we attempt to make an order in the application of the notion of visibility to the needs of TDA in a military sense, where a target is the main object of interest, standing in the environment of other, most frequently, irrelevant non-target objects. The notions of conspicuity and saliency of a target will be the subject of our forthcoming paper. The terms visibility, conspicuity, and saliency of a target can be considered synonyms and their interchangeability can be acceptable to some extent at qualitative description. However, once they are characterized by quantitative indices, they become no longer interchangeable. For this reason, in Section 2, we focus on quantitative definitions of visibility.

Quantitative definitions of visibility

1.1. Contrast and visibility definitions available in the literature. In military literature, it is widely accepted that quantitatively the visibility of a target is defined as the ratio of the Weber contrast of a target to the threshold Weber contrast still resolved by human eyes [2,3]. However, it should be noted that in the literature, there are several definitions of contrast [4] and an even greater number of techniques for target contrast measurements. Weber and Michelson's definitions are the two classical definitions. The Weber contrast

$$c_W = \frac{I_t - I_b}{I_b} \tag{1}$$

is used for a target (*t*) of the brightness I_t seen in an image against a uniform background (*b*) of the brightness I_b. For zero target brightness, one has $c_W\big|_{I_t=0} = -1$, whereas the upper limit of c_w values corresponds to a target seen against the background of vanishing brightness such that $c_W\big|_{I_b\to 0} \to +\infty$ and consequently the range of values for c_w is $c_W \in [-1,+\infty]$. Infinite contrast values would correspond to the infinite visibility when c_w given by Eq. (1) would be used for the determination of the visibility. In our opinion, in application to military needs a target of infinite visibility sounds at least confusing and thus is rather a disadvantage of such a definition.

Note that according to Eq. (1), positive values $c_w > 0$ correspond to a situation when the target brightness is higher than that of the background. We argue that a bright object against a dark background is not typical for real photographs taken in visible light, which are positive images in the sense of positive/negative photography while being typical for negative photography. Indeed, as a rule, a typical target object is solid, strongly absorbing visual light and consequently looking dark at least against the air background. A bright target against a dark background, which corresponds to the positive Weber contrast, is the very feature of a negative photograph. Such a controversy in the contrast sign convention is another disadvantage of the contrast definition in the form of Eq. (1).

In addition, the range of values $c_W \in [-1,+\infty]$ is essentially asymmetric with respect to zero, which is also rather inconvenient if one deals with the visual (Vis) and the infrared (IR) images where the same target as a rule appears to be of contrasts with the opposite signs in the Vis and IR images. The drastic difference in the scales $[-1;0[$ for the negative contrast values and $]0,+\infty[$ for the positive ones is at least unjustified theoretically and inconvenient regarding practical needs. The three disadvantages alluded to above demand the notion of contrast to be adapted for military target image description.

The definition of the Michelson contrast

$$c_M = \frac{I_{\max} - I_{\min}}{I_{\max} + I_{\min}}, \tag{2}$$

is used for the characterization of a stripe pattern with the periodical brightness varying along a line from its maximal value $I_{\max}$ to the minimal value $I_{\min}$. The range of values of the Michelson contrast is $c_M \in [0;+1]$. Although the definition of c_M serves for the characterization of a particular image pattern, therefore, implies only positive values, the form given by Eq. (2) is useful for the description of the contrast of a target if the variables $I_{\max}$ and $I_{\min}$ are replaced by the brightness values of the background I_b and of the target I_t. The resulting notion

$$K = \frac{I_b - I_t}{I_b + I_t}, \tag{3}$$

is called the normalized local contrast of a target [4].

The target normalized local contrast differs from the local contrast of the form [5] by the factor of 2

$$k = 2K = 2\frac{I_b - I_t}{I_b + I_t} = \frac{I_b - I_t}{\bar{I}} . \tag{4}$$

Respectively the ranges of values for these two forms of the local contrast are $k \in [-2;+2]$ and $K \in [-1;1]$. From Eqs. (3) and (4), it is seen that both forms of the local target contrast are free of the disadvantages listed above for the Weber contrast. Indeed, the ranges of values of both local contrast forms, firstly, include values of both (positive and negative) signs and thus are appropriate for the description of the target visibility in Vis and IR images. Secondly, their ranges of values are symmetric with respect to zero. Thirdly, their ranges of values are bound by finite numbers (not infinity as it is for the Weber contrast).

The target visibility, introduced as the ratio [2, 6]

$$\mathrm{v}_W = c_W / c_{th} , \tag{5}$$

based on the Weber contrast is an empirical parameter, showing how many times the target contrast exceeds the vision threshold c_{th}. Such a definition is rather inconvenient. First, according to Eq. (1) when the maximal possible value of c_w diverges to infinity the same does the visibility v_w. In our opinion, infinite visibility sounds, at least, confusing. Another inconvenience of the definition of visibility in the form of Eq. (5) is that the unit value of the visibility $v_w = 1$ corresponds to the condition $c_w = c_{th}$, which is at the limit of the target visibility. Conventionally, in the literature, the value of an image quality index equal to 1 is associated with the maximal image quality rather than with a lower limit, which in fact implies zero visibility below this limit. The aim of this paper is to introduce a target visibility index appropriate for the characterization of military targets in the partial (visible and infrared) and fused images from target sight-seeing systems of armored vehicles and to develop a technique for its measurement.

1.2. Target visibility index. To use visibility as a quantitative quality index for an image its range of values should fall in the interval $[0;1]$. Intuitively one understands that the notion of visibility is of a probabilistic character. The range of values for a probability as such is also $[0;1]$. In this respect, it is worth noting that the absolute value $|K|$ of the local contrast given by Eq. (3) is nothing else but the probability that a target of the brightness I_t is detectable (including computer-based detection) in an image against a background of the brightness I_b. Note that *per se* the normalized brightness with its range of values $I \in [0;1]$ is also a probability. Namely, I_t can be considered as the probability to detect a target in the absence of a background and vice versa I_b is the probability to detect a background in the absence of a target. The absolute value of their difference $|I_b - I_t|$ is nothing else but the conditional probability to detect a target against a background or vice versa to detect a background in the presence of a target. The denominator $\bar{I} = (I_b + I_t)/2$ in Eq. (4) (*mutatis mutandis* $I_b + I_t$ in Eq. (3)) can be considered as the total probability to detect either a target or background. Then $|K|$, which is the ratio of the conditional probability to the total probability is in the form of Bayesian probability [7] of detecting a target against a background.

However, even the absolute value $|K|$ of the normalized contrast given by Eq. (3), is by its sense the probability, it is not equivalent to the visibility of a target. An image quality index that would describe the target visibility should satisfy, at least, the following requirements. First, the notion of the threshold local contrast $|K_{th}|$, still (or no longer) resolved by human eyes, must be involved in the definition of visibility. Second, the visibility index should not be a singular function. Third, visibility is a notion strongly related to the neuronal response of the human brain and, thus, should be in the form of an activation function [8]. Forth, the target visibility index (TVI) should be of the probability character. Fifth, the visibility index should be target-oriented characterizing the target visibility against the near-field background.

The probability to catch the target against a cluttered background with a single glimpse is covered by the notions of the conspicuity and saliency of a target. In the literature, one finds several different definitions of these terms from purely qualitative characteristics to quantitative indices supplemented by specially designed methods for their measurement. For example, in [1] the term visibility is defined as: "the quality, state or degree of being capable of being seen", while the term conspicuity is defined as: "how well the detail stands out from the background". In many cases, the terms visibility and conspicuity are used interchangeably. Our analysis of the literature shows that the definitions of these key terms highly depend on the aim of their application. In this paper we attempt to make an order in their application to the needs of TDA in a military sense, where a target is the main object of interest, standing in the environment of other, most frequently, irrelevant non-target objects. The terms visibility, conspicuity, and saliency of a target can be considered synonyms and their interchangeability can be acceptable to some extent in the image assessment. However, once they are characterized by quantitative indices, they become no longer interchangeable. For this reason, in this and forthcoming papers we focus on quantitative definitions of these terms.

A target per se is neither visible/invisible nor conspicuous/inconspicuous. Both notions of visibility and conspicuity imply that a target is observed against a background. Below, in this section, we define the target visibility index via the target local (near-field) contrast against a uniform background. If a target stands against a sufficiently cluttered background, then one uses the notion of target conspicuity. One says that a target is conspicuous if it is detectable against a cluttered background of the whole image. Generally one says that the conspicuity of an object lowers due to the lateral masking by similar objects or more generally by a non-uniform cluttered background around the object. Lateral masking by the cluttered background is thus one of the factors affecting the target conspicuity [9-15] In turn, the visibility of the target is only one of the factors governing its conspicuity. The higher the visibility of the target the more conspicuous it is.

We will develop the consideration of the conspicuity and saliency of the target in the forthcoming paper.

If a target in an image stands against a sufficiently cluttered background, then to measure the local contrast, which is needed to calculate the target visibility index, one measures the brightness of the background I_b as an average of the brightness values across the horizontal line segment of the length, which is equal to the half-width of the target on both sides of the target [4]. The latter way of measurement is equivalent to the observation of the target in the regime when the image is zoomed until the target is observed against a more or less uniform local background. When measuring the visibility of a target one assumes also that the size of the target is much larger than the linear resolution of the camera or display, whichever is larger. Therefore the target visibility index characterizes the visibility of the object against its local uniform background. The TVI is a measure of the property of the very object; it does not account for the presence of other non-target elements of the image, which might mask the target.

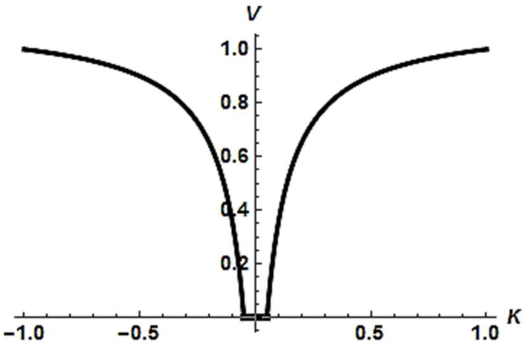
It should be noted that the absolute value $|K|$ of the normalized local contrast given by Eq. (3) is the probability to detect a target for given brightness values of the target and background without the account for the threshold character of human vision ability, i.e. without the account for the threshold contrast $|K_{th}|$. The conditional probability P to detect a target against a background at the given values of $|K|$ and $|K_{th}|$ is the difference between the probabilities of detecting $|K|(1-|K_{th}|)$ and non-detecting $|K_{th}|(1-|K|)$ a target

$$P = |K|(1-|K_{th}|) - |K_{th}|(1-|K|). \qquad (6)$$

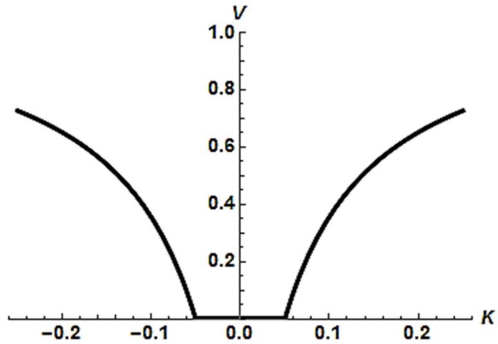
We define the image quality index, which describes the target visibility as the Bayesian probability

$$V = \begin{cases} \dfrac{P}{P_0} = \dfrac{|K|(1-|K_{th}|) - |K_{th}|(1-|K|)}{|K|(1-|K_{th}|) + |K_{th}|(1-|K|)} \; at \; |K| \ge |K_{th}| \\ 0 \; at \; |K| < |K_{th}| \end{cases} \qquad (7)$$

where $P_0 = |K|(1-K_{th}) + |K_{th}|(1-|K|)$ is the total probability of both events of detecting and non-detecting the target. Further throughout the text we call the parameter V, given by Eq. (7), the *target visibility index* (TVI) to distinguish it from other definitions of the visibility available in the literature. The plot $V(K)$ for $|K_{th}| = 0.05$ is shown in Fig. 1 for the full range $K \in [-1;1]$ (Fig. 1a) as well as in the close proximity between the positive and negative values of the threshold contrast in the range $K \in [-0.25;0.25]$ (Fig. 1b).



(a)

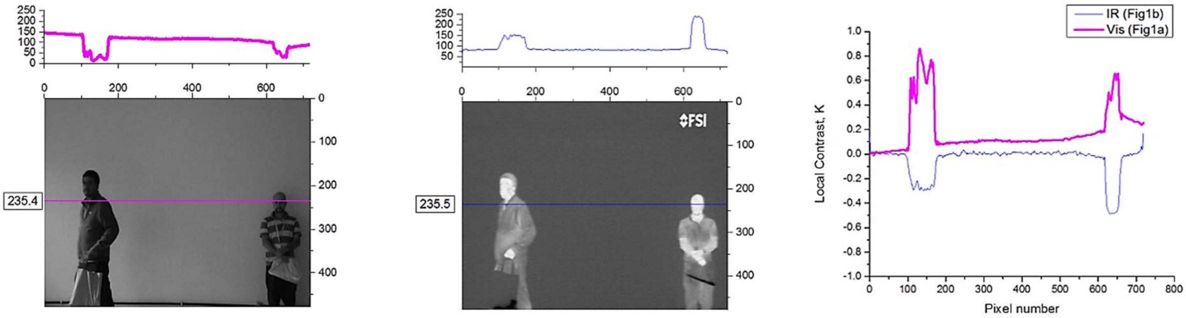


(b)

Fig.1. **Target visibility index V as a function of the target normalized local contrast K for (a) $K \in [-1;1]$ and (b) $K \in [-0.25;0.25]$ at $|K_{th}| = 0.05$**

It is easy to check that the analytical form of the TVI, V, given by Eq. (7), satisfies all five requirements listed above. Indeed, first, it involves the threshold contrast $|K_{th}|$. Namely, $V|_{K=K_{th}} = 0$, *i.e.* the target visibility index is zero at $K \le K_{th}$.Importantly, the effect of the threshold contrast drops down when the local contrast values increase; the effect of $|K_{th}|$ vanishes when $|K|$ approaches its maximal value $|K| = 1$. Second $V(K)$ is not singular within the whole range $V \in [0;1]$ of its values for whole range of the variable values $K \in [-1;1]$. Third, the function $V(K)$ is of the type of a nonlinear activation function such that $V|_{K \in [-K_{th};K_{th}]} = 0$ with sharp increasing followed by the saturation to $V|_{|K| \to 1} \to 1$ in the range $K \in]K_{th};1]$ Forth, by its physical sense the TVI is of the form of Bayesian probability to detect a target at the nonzero threshold contrast. Fifth, the TVI is calculated from the data of the target local contrast, which provides its target-oriented character.

A method for the measurement of the target local contrast K was proposed in our previous paper [4]. Below, in this subsection, we demonstrate how to determine the target visibility index for experimental input Vis and IR images of the same scene as well as those fused by different express image fusion techniques. Input partial Vis and IR images are shown in Figs. 2a and 2b, respectively. In the Vis image (Fig. 2a) one clearly recognizes the faces of two men but does not see what they carry in the bags that they hold in their hands. Contrarily, in Fig. 2b one detects the dangerous objects resembling a gun carried by the person on left and a knife by the person on right, however, their faces are not recognizable.



(a) (b) (c)

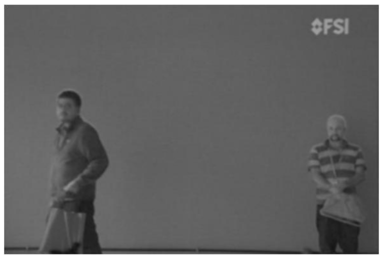
Fig. 2. **Input partial (a) Vis and (b) IR images with a uniform background and (c) the local contrast K, measured along lines drawn across the face of the person on right from the brightness data displayed above the photos**

The local contrast K, measured along a horizontal line drawn across the face of the person on right at the same vertical coordinate on both (Vis and IR) images is shown in Fig. 2c as a function of the horizontal coordinate. The details of the measurement procedure for the target local contrast K are given in our recent paper [4]. In Fig.2, the face of the person on right serves as a target. The same measurements were performed for other targets (the face of the person on left and the gun in his bag as well as the knife in the bag of the person on right). The partial Vis (Fig. 2a) and IR (Fig. 2b) images were fused by the algorithms of several target-oriented image fusion methods, namely by: the arithmetic average algorithm (Fig.3a) of the weighted addition method, root-mean-square (RMS) algorithm (Fig. 3b) of the complex-scalar method, geometric mean (Fig. 3c) and ellipticity (Fig. 3d) of the complex-vector method. The explicit forms of the fusion algorithms and detailed descriptions of the corresponding image fusion methods can be found in [4].

The results of the measurements of target local contrast and target visibility index are summarized in Table 1. The values of the TVI presented in Table 1 were calculated by the substitution of the data for the local contrast into Eq. (7) with .

a)

b)



c)

d)

Fig. 3. **Images fused with target-oriented image fusion methods by the algorithms of (a) arithmetic average, (b) RMS, (c) geometric mean, (d) ellipticity [4] with the input partial images shown in Fig. 2**

Table 1

Target local contrast K and target visibility index V for partial and fused images shown in Figs. 2 and 3

Image \ Target	Person on left				Person on right			
	Face		Gun		Face		Knife	
	K	V	K	V	K	V	K	V
Vis	0.65	0.945	0	0	0.54	0.854	0	0
IR	-0.49	0.896	0.71	0.958	-0.47	0.888	0.36	0.829
Arithmetic average	-0.17	0.591	0.31	0.790	-0.25	0.727	0.21	0.669
RMS	-0.17	0.591	0.4	0.854	-0.19	0.633	0.24	0.714
Geometric mean	0.31	0.790	0.58	0.927	0.20	0.652	0.26	0.779
Ellipticity	0.70	0.956	0.60	0.932	0.55	0.917	0.15	0.540

Visual inspection of Figs. 2, 3 and the analysis of data presented in Table 1 reveals that the partial Vis and IR images as well as the images fused by the arithmetic average algorithm are not appropriate for the simultaneous detection of dangerous objects and face recognition of the persons carrying them. Indeed, the Vis image (Fig. 2a) allows one to recognize the faces of persons; however, the objects which they carry are hidden in their bags. This conclusion is supported by the measured quantitative data for the local contrast and visibility index values measured for the faces of the persons (Table 1). Note, high enough values $K = 0.65$, $V = 0.98$ for the person on left and $K = 0.54$, $V = 0.94$ for the person on right. Importantly, the positive sign of the local contrast values for the person's faces indicates that the image in Fig. 2a can be used for face recognition. Were the corresponding local contrast values negative, the images would not be applicable for face recognition as it is in Fig. 2b showing the corresponding IR image. The corresponding local contrast values $K = -0.49$, $K = -0.47$ and the values of the target visibility index $V = 0.96$, $V = 0.95$ are quite high by the absolute values, however, the sign of the local contrast is negative, thus indicating that the IR image (Fig. 2b) is not appropriate for face recognition. Nevertheless, the IR image (Fig. 2b) carries important information showing that the persons carry dangerous objects in their bags. The values of the local contrast and visibility index are $K = 0.71$, $V = 0.98$ for the gun and $K = 0.36$, $V = 0.93$ for the knife in the IR image. The combination of the information carried by both Vis and IR images in one image is achieved by image fusion. Fig. 3 shows the images obtained by the fusion of partial Vis (Fig. 2a) and IR (Fig. 2b) images by four different algorithms. The analysis of the fused images presented in Fig. 3 and data for them in Table 1 reveals that the first two images fused by the arithmetic average (Fig. 3a) and RMS (Fig. 3b) algorithms are not appropriate for the simultaneous face recognition and detection of dangerous objects. Although Figs. 3a,b show dangerous objects carried by the persons in their bags, the local contrast values measured for the faces of persons are negative and thus not applicable for face recognition. Note that the values of the local contrast and visibility index measured for the images fused with the arithmetic average and RMS algorithms are considerably lower than the corresponding values for the input partial images. This is the known drawback of the algorithms based on image addition [5].

Considerably better results are obtained for the images fused by the geometric mean (Fig. 3c) and ellipticity (Fig. 3d) algorithms, which are based respectively on the multiplication and division of partial images. Both geometric mean and ellipticity fused images clearly display the dangerous objects. The faces of the persons are of positive local contrast, thus being applicable for the simultaneous detection of dangerous objects and face recognition. The values of the target visibility index and local contrast measured for the image fused by the ellipticity algorithm are higher than the corresponding indices for partial and other fused images.

Conclusions

Quantitative description of the quality of images from the military sight-seeing systems, particularly those of armored vehicles, implies specific approaches different from those used in traditional image processing for civilian needs. Our analysis of the literature shows that there are several disadvantages in the definitions of the quantitative image quality indices, which makes them inapplicable for the characterization of targets in images from military sight-seeing systems. An image quality index describing the target visibility should satisfy, at least, the following requirements. First, the notion of the threshold local contrast, still (or no longer) resolved by human eyes, must be involved in the definition of visibility. Second, the visibility index should not be a singular function. Third, visibility is a notion strongly related to the neuronal response of the human brain and, thus, should be in the form of an activation function.

Forth, the target visibility index should be of the probability character. Fifth, the visibility index should be target-oriented. We have proposed an expression defining the target visibility index which satisfies all five requirements and developed a technique for its measurement based on the measurements of the brightness profile along a line and calculation of the local contrast of the target. The measurements of the target visibility index are illustrated for the partial (visible and infrared) images and for images fused by algorithms of different target-oriented image fusion methods. The proposed target visibility index and the technique for its measurement enable selection of the fused image, which provides the highest visibility of the target. The comparison of the values of TVI allows one to make the selection of the best image manually by the operator or automatically with a computer.

References

1. Gary T. Yonemura and Karen Lister. (1990), A suprathreshold visibility meter to directly assess the conspicuity of office tasks : Report NISTIR 89-4226, U.S. Department of commerce National Institute of Standards and Technology National Engineering Laboratory Center for Building Technology Building Environment Division Gaithersburg, MD 20899. (Accessed January 2023).

2. Losyka O.A. (1983), *"Tanky (osnovi teoryy, konstruktsyy y boevoi efektyvnosty)"* [Tanks (basics of theory, design and combat effectiveness)] : Tutorial book 2, Moskva, VA BTV. 157 p. [in Russian].

3. Werner A. (1989), Visibility of Targets. *Transportation Research Record 1247*. pp. 39−45.

4. Khaustov D., Kyrychuk O., Stakh T., Khaustov Ya., Burashnikov O., Ryzhov Ye., Vlokh R. and Nastishin Yu. (2023), Complex-scalar and complex-vector approaches for express target-oriented image fusion. *Ukrainian Journal of Physical Optics*. Lviv. Vol. 24. № 1. pp. 62−82. DOI: https://doi.org/10.3116/16091833/24/1/62/2023 (Accessed: March 2023).

5. Khaustov Ya.Ye., Khaustov D.Ye., Lychkovskyy E., Ryzhov Ye. and Nastishin Yu.A. (2019), Image fusion for a target sightseeing system of armored vehicles. *Military Technical Collection*. Lviv. Issue № 21. pp. 28–37. DOI: https://doi.org/10.33577/2312-4458.21.2019.28-37 (Accessed December 2022).

6. Khaustov D.Ye., Nastishin Yu.A. and Khaustov Ya.Ye. (2021), "Ymovirnist vykonannia vizualnoi zadachi yak syhmoidna funktsiia" [Probability of the execution of the visual task as a sigmoid function]. *Науково-технічний журнал Озброєння та військова техніка.* Київ: ЦНДІ ОВТ ЗСУ. №3 (31). С. 80−94. DOI: https://doi.org/1034169/2414-0651.2021.3(31).80-94 (Accessed December 2021). [in Ukrainian].

7. James V Stone. (2013), Bayes' rule: a tutorial introduction to Bayesian analysis. Neural Information Theory Tutorial book, Sebtel Press, The University of Sheffield, Sheffield, South Yorkshire.169 p.

8. Santosh K. C., Nibaran Das and Swarnendu Ghosh. (2022), Chapter 2 - Deep learning: a review. In Primers in Biomedical Imaging Devices and Systems, Deep Learning Models for Medical Imaging : Tutorial, University of South Dacota, Vermillion, SD: Academic Press. 29−63 p. ISBN 9780128235041. DOI: https://doi.org/10.1016/B978-0-12-823504-1.00012-X

9. Engel F.L. (1971), Visual conspicuity. Directed attention and retinal locus : Tutorial. IfPR, Vision Research. pp. 563−575.

10. Engel F.L. (1977), Visual conspicuity, visual search and fixation tendencies of the eye : Tutorial. IfPR, Vision Research. pp. 95−100.

11. Wertheim A.H. (2010), Visual conspicuity: A new simple standard, its reliability, validity and applicability. *Ergonomics*. London: Taylor & Francis, pp. 421−442. DOI: http://dx.doi.org/10.1080/00140130903483705 (Accessed 25 February 2023).

12. Toet A., Biji P., Kooi F.L. and Valeton J.M. (1998), Quantifying target distinctness through visual conspicuity. *Partof the SPIE Conference on Targets and Backgrounds: Characterization and Representation IV.* Orlando, Florida: TNO HFRI. pp. 152−163. DOI: https://doi.org/10.1117/12.327149 (Accessed March 2023)

13. Thomas Porathe. (2008), Conspicuity index – looking for a possible objective measurement of visibility taking context into account. *Proceedings of the 40th Annual Conference of the Nordic Ergonomic Society*. Reykjavik, Iceland, August 11–13, ISBN 978-9979-70-471-3, URL: https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=29b20afa2d4bbcb06887992567bd5072541a5bf2 (Accessed Murch 2023)

14. Lijuan Duan, Chunpeng Wu, Jun Miao and Alan C. Bovik. (2011), Visual Conspicuity Index: Spatial Dissimilarity, Distance, and Central Bias. *IEEE SIGNAL PROCESSING LETTERS*. Vol. 18, No. 11. pp. 690-693.

15. Itti L., Koch C. and Niebur E. (1998), A model of saliency-based visual attention for rapid scene analysis. *IEEE Transactions on pattern analysis and machine intelligence*, Vol. 20. Issue 11. pp. 1254–1259. DOI: https://doi.org/10.1109/34.730558

Список літератури

1. Gary T. Yonemura, Karen Lister. A suprathreshold visibility meter to directly assess the conspicuity of office tasks : Report NISTIR 89-4226, U.S. Department of commerce National Institute of Standards and Technology National Engineering Laboratory Center for Building Technology Building Environment Division Gaithersburg, MD 20899. (дата звернення: 01.2023).

2. Лосика О.А. Танки (основы теории, конструкции и боевой ефективности) : учебн., кн. 2 / под ред.. М.: ВА БТВ, 1983. 157 с.

3. Werner A. Visibility of Targets. *Transportation Research Record 1247*. 1989, pp. 39−45.

4. Khaustov D.Ye., Kyrychuk O.A., Stakh T.M., Khaustov Ya.Ye., Burashnikov O.O., Ryzhov Ye., Vlokh R., Nastishin Yu. A. Complex-scalar and complex-vector approaches for express target-oriented image fusion. *Ukrainian Journal of Physical Optics.* Lviv. 2023. Vol. 24. № 1. pp. 62−82. DOI: https://doi.org/10.3116/16091833/24/1/62/2023 (дата звернення: 03.2023)

5. Khaustov Ya. Ye., Khaustov D. Ye., Lychkovskyy E., Ryzhov Ye., Nastishin Yu. A. *Військово-технічний збірник*. Lviv. 2019. Issue № 21. pp. 28–37.

DOI: https://doi.org/10.33577/2312-4458.21.2019.28-37 (дата звернення: 12.2022)

6. Хаустов Д.Є., Настишин Ю.А., Хаустов Я.Є., Андрієнко А.М. Ймовірність виконання візуальної задачі як сигмоїдна функція. *Науково-технічний журнал Озброєння та військова техніка.* Київ: ЦНДІ ОВТ ЗСУ, 2021. № 3 (31). С. 80−94. DOI: https://doi.org/1034169/2414-0651.2021.3(31).80-94. (дата звернення: 12.2021).

7. Stone James V. Bayes' rule: a tutorial introduction to Bayesian analysis. Neural Information Theory Tutorial book, Sebtel Press, The University of Sheffield, Sheffield, South Yorkshire. 2013. 169 p.

8. Santosh K. C., Nibaran Das, Swarnendu Ghosh. Chapter 2 - Deep learning: a review. In Primers in Biomedical Imaging Devices and Systems, Deep Learning Models for Medical Imaging : Tutorial, University of South Dacota, Vermillion, SD: Academic Press. 2022. 29−63 p. ISBN 9780128235041. DOI: https://doi.org/10.1016/B978-0-12-823504-1.00012-X

9. F.L. Engel, "Visual conspicuity. Directed attention and retinal locus", Vision Research, 1971. pp. 563−575.

10. Engel F.L. "Visual conspicuity, visual search and fixation tendencies of the eye", Vision Research, 1977. pp. 95−100.

11. Wertheim A.H. Visual conspicuity: A new simple standard, its reliability, validity and applicability. *Ergonomics*. London: Taylor & Francis, 2010. pp. 421−442. DOI: http://dx.doi.org/10.1080/00140130903483705 (дата звернення: 25.02.2023).

12. Toet A., Biji P., Kooi F.L., Valeton J.M. Quantifying target distinctness through visual conspicuity. *Partof the SPIE Conference on Targets and Backgrounds: Characterization and Representation IV.* Orlando, Florida: TNO HFRI. 1998. pp. 152−163. DOI: https://doi.org/10.1117/12.327149 (дата звернення: 03.2023)

13. Thomas Porathe. Conspicuity index – looking for a possible objective measurement of visibility taking context into account. *Proceedings of the 40th Annual Conference of the Nordic Ergonomic Society*. Reykjavik, Iceland, August 11–13, 2008. ISBN 978-9979-70-471-3, URL: https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=29b20afa2d4bbcb06887992567bd5072541a5bf2 (дата звернення: 03.2023).

14. Lijuan Duan, Chunpeng Wu, Jun Miao, Alan C. Bovik. Visual Conspicuity Index: Spatial Dissimilarity, Distance, and Central Bias. *IEEE SIGNAL PROCESSING LETTERS.* 2011. Vol. 18, No. 11. pp. 690-693.

15. Itti L., Koch C., Niebur E. A model of saliency-based visual attention for rapid scene analysis. *IEEE Transactions on pattern analysis and machine intelligence,* 1998. Vol. 20. Issue 11. pp. 1254–1259. DOI: https://doi.org/10.1109/34.730558

ІНДЕКС ВИДИМОСТІ ЦІЛІ

Хаустов Д., Киричук О., Стах Т., Хаустов Я., Сідор Р., Бурашніков О., Рижов Є., Настишин Ю.

Кількісна характеристика якості зображень із прицільно-спостережних комплексів, зокрема бронетехніки, передбачає специфічні підходи, відмінні від тих, що застосовуються при традиційній обробці зображень для цивільних потреб. Наш аналіз літератури показує, що є, як мінімум, кілька недоліків у визначеннях кількісних показників якості зображення, що робить їх непридатними для характеристики цілей на зображеннях із прицільно-спостережних комплексів. По-перше, кількісні показники, які описують якість зображень, що вводяться для цивільного застосування, і методики їхнього вимірювання не є цілеорієнтованими. У більшості випадків індекси якості зображення, доступні в літературі, характеризують зображення як ціле, але, виявляються такими, що не мають ніякого відношення до видимості та помітності цілі. Високі показники якості зображення не гарантують високої видимості та помітності цілі. Навпаки, часто висока контрастність цілі супроводжується ненормальним (надзвичайно високим або низьким) освітленням фону, цілі або обох, що покращує видимість і помітність цілі, але передбачає низькі показники якості зображення як цілого. По-друге, визначення контрасту, видимості та помітності цілі, доступні в літературі, не є симетричними відносно нуля, а деякі з них є сингулярними функціями. Ми стверджуємо, що індекс якості зображення, який описує видимість цілі, повинен задовольняти принаймні наступним вимогам. По-перше, поняття порогового локального контрасту, який все ще (або уже не розрізняється) людським оком, має бути залучено до визначення видимості. По-друге, індекс видимості не повинен бути сингулярною функцією. По-третє, видимість − це поняття, тісно пов'язане з нейронною реакцією людського мозку, і, отже, має бути у формі функції активації. По-четверте, індекс видимості цілі повинен мати ймовірнісний характер. По-п'яте, індекс видимості повинен бути цілеорієнтованим. У цій статті ми пропонуємо вираз, що визначає індекс видимості цілі, який задовольняє усім п'ятьом вимогам, перерахованим вище, і розробляємо методику його вимірювання на основі вимірювань профілю яскравості вздовж лінії та розрахунку локального контрасту цілі. Вимірювання індексу видимості цілі проілюстровано для вхідних (видимого та інфрачервоного) зображень, а також для зображень, комплексованих за алгоритмами різних цілеорієнтованих методів злиття зображень.

Keywords*: локальний контраст, видимість, помітність, помітність цілі, індекс видимості цілі, цілеорієнтоване злиття зображень.*