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Evaluation of the Camouflage Effect of Decorative Pieces on Camouflage Net Highly Fused with Background Based on Image Processing

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Abstract. The evaluation of camouflage effect can be efficiently completed through computer digital image processing. The decorative pieces on the camouflage net can effectively ameliorate the camouflage effect of camouflage net. In an effort to evaluate the camouflage effect of decorative pieces on the camouflage net, our research group organized experiments for research. This study used decorative pieces with different edge shapes, and determined the type of camouflage net used in the background through color extraction. The study compared the performance differences of camouflage before and after adding decorative pieces to obtain the research results based on computer image processing. As the research results clearly reveal, decorative pieces on the camouflage net can effectively heighten the effectiveness of camouflage net camouflage net, providing a method for quantitatively evaluating the camouflage effect of decorative pieces on the camouflage net through computer digital image processing.

Keywords. Image processing, Camouflage Net, Decorative Piece, Camouflage Effect

1. Introduction

Camouflage can effectively improve the survival of targets and play an important role [1-3]. Among numerous equipment and equipment, camouflage nets are the most widely used. How to evaluate the effectiveness of camouflage nets in practical use has always been a challenge [4-6]. The evaluation of camouflage effect is a quantitative evaluation of the degree of camouflage of a target. The evaluation of camouflage effect is to place the camouflage target in the background of the camouflage environment and evaluate its "survival" probability, that is, whether it is possible to be discovered during investigation and how likely it is to be discovered. Many researchers define a similarity value, and the larger the overall similarity value, the better the camouflage effect. These methods can be used for evaluating the camouflage effect of camouflage net decorative pieces, but they also have their own characteristics. In fact, the evaluation of camouflage effect can rely on image processing methods. By collecting images, extracting relevant image data, and quantitatively analyzing the differences between the target and the background [7-

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10], data support can be provided for quantitative evaluation of camouflage effect. Highly fused decorative pieces on the camouflage net can augment the fusion degree between camouflage net and background, and reduce its edge features [11-12]. As a consequence, flexible implementation can be organized according to the actual situation, which can easily and quickly heighten the level of camouflage for our important goals. This can deal with the problem of the fixed color matching of camouflage net being difficult to adapt to global and multi terrain applications. However, it is worth exploring how to quantify and compare the camouflage effects before and after using decorative pieces on the camouflage net, how to select decorative pieces on the camouflage net, how to guide the use of camouflage net decorative pieces in troops, and further ameliorate the performance of camouflage net use, thus making the application of camouflage net more practical.

2. Demonstration of decorative piece experimental effects

The optical effect before and after adding decorative pieces is displayed in Figure 1 and Figure 2. Aside from that, the camouflage net and background color difference in the two images are calculated accordingly. Then, the automatic threshold log operator is used for edge detection performance verification, as exhibited in Figures 3 and 4.

Figure 1. Effect image before adding decorative pieces

Figure 2. Effect image after adding decorative pieces

Figure 3. Edge detection image before adding decorative pieces

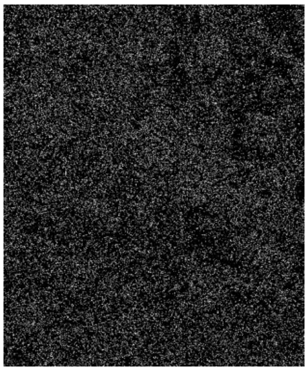

Figure 4. Edge detection image after adding decorative pieces

3. Analysis and Evaluation on the Camouflage Effect of Decorative Pieces

The camouflage effect is the degree to which camouflage conceals our side and deceives the enemy. The purpose of developing and using highly fused decorative pieces on the camouflage net is to improve camouflage net. The evaluation of camouflage effect requires the establishment of a scientific and reasonable indicator system, as well as the establishment of a scientific and feasible camouflage effect evaluation method.

In general, the comprehensive detection probability of targets depends on the optical detection probability, thermal infrared detection probability, (multi) spectral detection probability, and microwave detection probability. Owing to the use of multi band absorbing materials in the decorative piece on this highly fused camouflage net, this article focuses on evaluating and analyzing the optical camouflage effect.

The probability of optical discovery of targets depends on the color and brightness characteristics of the target background, as well as the shape scale characteristics of the target. As a result, this article selects three variables: color, brightness, and contour deformation to evaluate and study the camouflage effect of decorative pieces.

3.1. Color

Color is a visual effect on light generated through the eyes, brain, and our life experiences. The light we see with the naked eye is generated by electromagnetic waves with a narrow frequency range. Electromagnetic waves of different frequencies exhibit different colors. Besides, color recognition is a visual nerve sensation caused by the stimulation of electromagnetic wave radiation energy to the naked eye.

This topic uses a color space, also known as a color model (also known as a color space or color system) that explains colors in a generally acceptable manner under certain standards to facilitate the quantification of the camouflage effect of decorative pieces. There are many types of color spaces, commonly used including RGB, CMY, HSV, HSI, etc. The color space of HSV is more in line with human understanding of color, so this article chooses it as the model for this study.

In this study, the cumulative differences in color distribution of images before and after using decorative pieces in the HSV color space is compared. The results are exhibited in Table 1.

Table 1. color difference between background and target

	H	S	V
No decorative piece used	1827974	2127074	1677064
After using decorative pieces	1418064	1614042	1658206

After calculation, H, S, and V value of the target and background were reduced by 21.42%, 17.00%, and 36.27%, respectively, after using decorative pieces. This proves that using decorative pieces in the HSV color space can effectively lower the difference between the target and the background, thereby improving the fusion degree of camouflage net.

3.2. Grayscale

Apart from analyzing the color contrast between the target and the background, in order to evaluate the effect of the significance of the camouflage net edge features after using decorative pieces, it is also essential to consider the difference in the grayscale distribution between the target and the background.

In grayscale images, brightness equals grayscale, and the image processing method is the same. The grayscale uses a black tone to represent objects, using black as the reference color and displaying images with different saturation levels of black. Each grayscale object has brightness values ranging from 0% (white) to 100% (black). Using black tones to represent objects, that is, using black as the reference color and displaying images with different saturation levels of black. Most objects in nature have an average grayscale level of 18%. The discontinuity of grayscale is present at the edges of objects. Besides, the image segmentation used in edge detection is based on this principle.

The grayscale histogram of the target and background is made to analyze and reflect the grayscale distribution. This article divides grayscale into 16 categories, with the middle value as the clustering value, as displayed in Table 2.

Table 2. Grayscale histogram of target and background to reflect grayscale distribution

Range	Grayscale Value	Range	Grayscale Value
0-15	8	128-143	136
26-31	24	144-159	152
32-47	40	160-175	168
48-63	56	176-191	184
64-79	72	192-207	200
80-95	88	208-223	216
96-111	104	224-239	232
112-127	120	240-250	248

The grayscale histogram system before and after adding decorative pieces is comprehensively compared. The brightness distribution before and after adding decorative pieces is displayed in Figure 5 and Figure 6. The results of the grayscale difference values in each interval before and after adding decorative pieces are illustrated in Table 3.

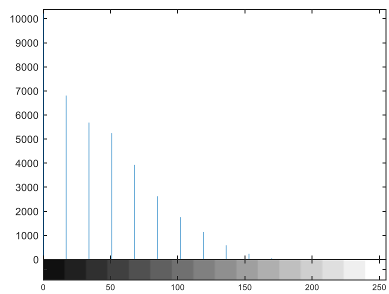

Figure 5. Brightness distribution before adding decorative pieces

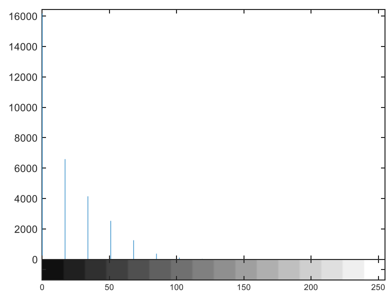

Figure 6. Brightness distribution after adding decorative pieces

Table 3. Grayscale difference values before and after adding decorative pieces

Grayscale value	8	24	40	56	72	88	104	120	136
Grayscale difference without using decorative pieces	54456	136416	209880	220024	189000	154616	118872	70800	31960
Grayscale difference without using decorative pieces	47376	118488	165320	159600	123048	69784	28184	11280	4352

From the grayscale histogram, it can be intuitively seen that the difference in grayscale between the target and the background is significantly reduced before and after using decorative pieces, especially in the grayscale range [88136] where the difference in grayscale between the target and the background before and after using decorative pieces is reduced by more than 50%. After calculation, the color difference is reduced from 1186024 to 727432, with a reduction of 38.66%, reaching the expectation of making the target grayscale distribution closer to the surrounding background to better the camouflage effect.

3.3. Contour Deformation

As the analysis on the morphological features of the spatial color mixing effect shows, the camouflage net with a square as the main shape is a good shape (good shape, also known as good shape, is a type of visual stimulation. It refers to a shape with a tight and complete structure, clear outline, and meaning that can be expressed) that is easily detected and recognized by the enemy. The purpose of using decorative pieces is to use various irregular patches to damage the original contour of the target and deform it, which breaks the original boundary between the camouflage target and the background, causes the target contour to deform, thereby increasing the difficulty of enemy reconnaissance and identification of the target, thus achieving the purpose of camouflage.

Research has found that the contour of the target undergoes deformation before and after the camouflage, known as ‘contour deformation degree’, which has a significant impact on the camouflage effect. In general, the larger the deformation of the target contour, the less easily the target is identified, and the better the camouflage effect. To calculate the contour deformation of the camouflage target, the first step is to extract the contour features of the target. The relevant literature puts forward a method of binary statistical moments to obtain the contour features of the target, calculate the contour deformation, and obtain the evaluation results of the camouflage effect. This project uses contour deformation to quantify the difference between the target shape scale and background to analyze the improvement of camouflage effect. The basic calculation steps are as follows:

Step 1: Calculate the Euclidean distance and cosine distance of the contour feature vector. Calculate the binary statistical moments of any two images separately, then convert them into contour feature vectors, subsequently calculate Euclidean distance and cosine distance for these two vectors.

Step 2: Calculate the contour deformation value. Calculate the contour deformation value as follows.

$$y = \frac{1}{ad+cu} \tag{1}$$

$$a+c=1 \tag{2}$$

Where d represents the Euclidean distance, u represents the cosine distance, a and c are weight values constrained by equation (4), and y is the contour deformation value under the current weight allocation.

Step 3: Calculate and obtain the result set of contour deformation values by exhaustive weighting.

The so-called exhaustive weighting method refers to allocating all possible weights within a certain interval with a fixed step size. For example, with a step size of 0.001 and calculated within the [0,1] interval, the weight coefficient can be (a=0.001, c=0.999), or (a=0.002, c=0.998), etc. Apart from that, 999 possible weight assignments can be exhaustively listed. The results of each weight allocation calculation form an element in the contour deformation degree result set, until all the weight coefficients are exhaustively calculated, and a result set of contour deformation degree values is obtained finally.

To determine the value of the weight coefficient, the following equation can be used, where a represents the weight value in equation, n represents the counter, and s represents the step size. a=n × s

$$n \subseteq \left[0,\frac{1}{s}\right] \tag{3}$$

Step 4: Obtain the final contour deformation value through single-element regression.

The contour deformation degree result set calculated in step 3 is subjected to single-element regression, as illustrated in the following equation (k represents the fluctuation degree of contour deformation degree, b represents the contour deformation degree value). As exhibited in the following equation, the linear relationship between x and y values can be obtained. Finally, a b value in the [0,1] interval is obtained, which is the final contour deformation degree

$$\min[f(x)] = \sum_{i=1}^{n}(y_i - \overline{y_i})^2 = \sum_{i=1}^{n}[y_i - (k + bx_i)]^2 \tag{4}$$

$$y=kx+b \tag{5}$$

At this point, the calculation of contour deformation is completed.

The results of contour deformation calculation for the background image, the target image 2 after using decorative pieces, and the target image 1 before using decorative pieces are 0.23635, 0.18313, and 0.29103, respectively.

As the results clearly reveal, the complexity of the contour before using decorative pieces is lower than that of the background, while the complexity of the image contour in the camouflage scheme after using decorative pieces significantly increases. This is resulted from the reduction of good images and also in line with the definition and application of contour complexity.

4. Conclusion

The camouflage effect evaluation method based on image processing provides a way to efficiently and quantitatively evaluate the camouflage effect. This project puts forth a method for evaluating the effectiveness of camouflage using decorative pieces on the camouflage net, which mainly includes three indicators: color, grayscale, and contour deformation. From the experimental results, the three indicators have effectively quantified the camouflage effect, providing a quantitative basis for determining the color types and specific usage scenarios of decorative pieces, and have significant practical value. The camouflage net decorative film has been proven through experiments to significantly improve the camouflage effect and has important practical value. In complex and ever-changing environments, the diversity of equipment can be increased. However, the color of the decorative piece is limited, and if the color change of the decorative piece can be achieved, the camouflage effect that adapts to the background will be more prominent. The use of computer vision for digital image processing will provide a new tool for evaluating the camouflage effect of decorative films, which will be widely applied in camouflage effect evaluation.

References

[1] Mikkelsen A., Selj Gorm K. Spectral reflectance and transmission properties of a multi-layered camouflage net: Comparison with natural birch leaves and mathematical models. Target and Background Signatures VI, 2020, 11536.

[2] Jaydeep S., Dharmendra S. An Analytical Approach to Design Camouflage Net for Microwave Absorption. Defence Science Journal, 2019, 69(5): 469-473.

[3] Futagami T., Hayasaka N. Automatic Extraction of Building Regions by using Color Clustering. SICE Annual Conference 2019.

[4] Chen J., Xing H., Chen X. Automatic Building Extraction from Remote Sensing Images Based on Cascaded CRFs and the U-Net Deep Learning Model. Journal of South China Normal University (Natural Science Edition), 2022, 54(1): 70-78.

[5] Zoe D. D. Shampoos, Conditioners, and Camouflage Techniques. Dermatologic Clinics, 2013, 31(1): 173-178.

[6] He Z., Gan Y., Ma S., Liu C., Liu Z. Evaluation method for the hyperspectral image camouflage effect based on multifeature description and grayscale clustering. EURASIP Journal on Advances in Signal Processing, 2023, 2023(1): 11.

[7] Juntang Y., et al. Research on camouflage effect evaluation method of moving object based on video. Acm Siggraph Conference, ACM, 2016: 441-446.

[8] Wilder J., Feldman J., Singh M. The role of shape complexity in the detection of closed contours. Vision Research, 126(2016): 220-23.

[9] Wang K., Liu Z., Wang Y., et al. Evaluation of Optical Camouflage Effect Based on Entropy Weight TOPSIS Method. International Conference on Signal Image Processing and Communication. 2021.

[10] Xiao W., Zhao Y., Gao X., et al. Implementation of Fuzzy C-Means (FCM) Clustering Based Camouflage Image Generation Algorithm. IEEE Access, 2021.

[11] Xu X., Zhu M., Yu J., et al. Boundary guidance network for camouflage object detection. Image and Vision Computing, 2021, 114(4): 104283.

[12] Yao Q., He Z., Lin Y., et al. A Hierarchical Feature Constraint to Camouflage Medical Adversarial Attacks. Medical Image Computing and Computer-Assisted Intervention. Springer, Cham, 2021.