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Research on the Using Methods of Decorative Pieces on Camouflage Net Highly Fused with Background Based on Computer Vision

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Abstract. The technological development of computer vision provides a new path for improving camouflage effects. As an important means of anti-reconnaissance, camouflage plays an important role in competing for information superiority. In an effort to ameliorate the camouflage effect of camouflage net based on computer vision, a method of using decorative pieces on the camouflage net was proposed, and the color determination and fixation methods of decorative pieces were studied. Taking forest type camouflage net as an example, this article compared the similarity of edge and color distribution before and after adding decorative pieces for experiments; Through comprehensive analysis of cost-effectiveness and universality, this article determined the color types and specific color information of the decorative piece production; This study determined the usage of decorative pieces and camouflage net through the average time of repeated experiments. On the basis of the above experiments and analysis, the color variety, layout, shape and size of highly fused decorative pieces on the camouflage net were determined, which provides a brand-new method for improving the camouflage effect of camouflage net based on computer vision.

Keywords. Computer vision, digital image processing, image clustering, color difference

1. Introduction

There is a close connection between computer vision and camouflage net decorative films. Computer vision technology provides strong support for the design, production, and evaluation of camouflage net decorative films. Through computer vision algorithms, we can automatically identify and analyze the performance of camouflage net decorative pieces in the target environment [1], such as the matching degree between features such as color, texture, shape, and the target background. These analysis results can help us optimize the design of camouflage net decorative panels and improve the camouflage effect. Meanwhile, computer vision can also be used for automated evaluation of camouflage effects, reducing the subjectivity and errors of manual evaluation. Therefore, the development of computer vision technology will provide strong technical support for the innovation and improvement of camouflage net decorative films.

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The camouflage net in the camouflage screen is featured by high cost-effectiveness, easy and fast laying, as well as desirable camouflage effect [2]. As a result, reasonable use of camouflage net can lessen the probability of enemy reconnaissance as well as surveillance detection and identification, lower the probability of enemy firepower attack hit, and thus heighten the target survival ability [3]. Nonetheless, camouflage net has two prominent shortcomings. To begin with, the type of camouflage net is fixed, making it difficult to adapt to various terrain color backgrounds in China, and the effectiveness of responding to enemy reconnaissance and surveillance equipment is limited [4]. Furthermore, the edge features of camouflage net are significantly less fused with the surrounding background, making it easy for detection equipment to recognize [5]. The use of highly fused decorate-ve pieces on the camouflage net can heighten the fusion between the camouflage net and the background, and reduce its edge features [5]. To be specific, we can adopt technology to organize flexible implementation on the basis of actual situations, which can easily and quickly ameliorate the camouflage level of our important target [6]. This can cope with the problem of the fixed color matching of camouflage net being difficult to adapt to global and multi terrain applications [7]. The development of computer image processing technology, especially image clustering technology, provides a method for accurately extracting background colors. Thus, it is more convenient to achieve a high degree of integration between the camouflage net decorative film and the local background, ensuring a good camouflage effect [8]. To sum up, conducting evaluation research on camouflage effect of highly fused decorative pieces on the camouflage net can not only further ameliorate the performance of camouflage net usage, but also make its application more practical.

2. Color determination based on Computer Vision

Using computer vision to determine the color of the camouflage net decoration is a crucial step, which involves in-depth analysis and understanding of the target environment background. Firstly, by collecting image data of the target environment, we can use computer vision algorithms to preprocess these images, such as denoising and enhancement, to improve image quality [9]. Then, using color segmentation and clustering algorithms, the colors in the image are classified and statistically analyzed to obtain the main color distribution and features of the target environment. Furthermore, based on these color features, we can design a color scheme for the camouflage net decorative film to coordinate with the target environment and achieve better camouflage effects [10]. Finally, using computer vision evaluation methods, the color scheme of the designed camouflage net decorative film is tested and optimized to ensure its effectiveness in practical applications.

The specific techniques of computer vision can be used to enhance the camouflage effect of camouflage net decorative pieces through the following steps: Image acquisition and processing: Firstly, use a high-resolution camera or image acquisition device to obtain images of the camouflage net decorative film [11]. Then, through image preprocessing techniques such as denoising and contrast enhancement, the image quality is improved, providing clear image data for subsequent analysis and processing. Image denoising is an important step in the preprocessing process, with the main purpose of eliminating or reducing noise in the image. The denoising method used here is mean filtering, which replaces the value of each pixel with the average value of its neighboring pixels, effectively reducing random noise in the image. The main purpose of contrast enhancement is to improve the visual effect of the image, making the details in the image clearer. The contrast enhancement method here is histogram equalization, which stretches the histogram of the image to make the distribution of pixel intensity more uniform, thereby improving the contrast of the image. Adaptive histogram equalization is an improved method that divides an image into small blocks and applies histogram equalization to each block to avoid over enhancing details.

Feature extraction: Utilizing feature extraction techniques in computer vision, such as 3edge detection, texture analysis, color space conversion [12], etc., to extract key features of the camouflage network from preprocessed images. These features may include edge contours, texture patterns, color distribution, etc. Image fusion: fuse the extracted camouflage network features with the background image. This can be achieved through image fusion algorithms such as multi-scale fusion, wavelet transform fusion, Laplace pyramid fusion [13], etc. These algorithms can effectively combine the features of the camouflage net with the background image, making it look more natural and coordinated. Edge detection operators include Canny operator, Roberts operator, Prewitt operator, and Sobel operator. These operators detect edges by calculating changes in pixel intensity in the image. The specific steps include applying edge detection operators to the preprocessed image. Determine which pixels belong to the edges based on the set threshold. Connect these edge pixels to form continuous edge lines, thereby revealing the structure of the camouflage network. Texture is the pattern of arrangement and intensity changes of local pixels in an image. The specific method is to use texture analysis methods such as grayscale co-occurrence matrix, autocorrelation function, or wavelet transform. Color space conversion and camouflage networks may exhibit distinct features in specific color spaces. Convert the preprocessed image from RGB space to the target color space. Analyze the color distribution, brightness, or saturation characteristics of the camouflage network in a new color space. Based on these features, extract key information of the camouflage network.

Real time adjustment and optimization: Based on actual application scenarios and camouflage requirements, adjust and optimize the fused image in real time. This may include adjusting fusion parameters, optimizing texture mapping, enhancing color consistency, and so on. These adjustments aim to further improve the camouflage effect of the camouflage net, enabling it to maintain good camouflage performance under different environmental conditions. Camouflage effect evaluation: Finally, evaluate the improved camouflage effect through quantitative and qualitative evaluation methods [14]. This can include methods such as manual observation and automatic evaluation based on computer vision. Based on the evaluation results, the camouflage effect of the camouflage net decorative film can be further optimized and improved.

2.1. Establish a Standard Color Library

Establish a standard color library for camouflage net decorative pieces, which requires clear application scenarios and target requirements. For the military field, the design of color libraries has different focuses. It collects and organizes commonly used colors for various camouflage net decorative pieces, including natural colors, camouflage colors, etc., to ensure a rich and practical color library. Meanwhile, a standardized color-coding system is adopted to ensure the accuracy and consistency of colors. And establish a management mechanism for color libraries, regularly update and maintain them to adapt to constantly changing market demands and technological developments.

This study referred to the standard color library for the most widely needed green, sandy, and neutral colors that meet the background environment, and used software to extract the L, a, and b information of the colors.

The general process and details of constructing a camouflage standard color library:

2.1.1. Clarify goals and requirements

Determine the application areas and purposes of the camouflage standard color library, such as military camouflage, product design, etc. Analyze the needs of the target user group and understand their specific requirements and expectations for camouflage colors.

2.1.2. Collect and organize information

Collect existing camouflage color data, including various color samples, color cards, images, etc. Screen, classify, and organize the collected data to ensure its accuracy and reliability.

2.1.3. Develop color standards

Develop appropriate color standards and specifications based on the application field and target user group. Determine the naming, numbering, hue, brightness, saturation, and other parameters of colors to form a unified color description system.

2.1.4. Establish database architecture

Design database structure, including table structure, field definitions, data relationships, etc. Determine the storage method, access permissions, and data backup strategy for the database.

2.1.5. Data entry and verification

Input the organized camouflage color data into the database to ensure the completeness and accuracy of the data. Verify and verify the entered data to ensure its accuracy and consistency.

2.2. Color Clustering

To achieve color clustering of camouflage net decorative pieces, it is necessary to collect color data of camouflage net decorative pieces and use professional color extraction techniques to obtain the main color information from each piece of decorative piece. Utilize color space conversion to convert color data into a format suitable for clustering. Choose an appropriate clustering algorithm, such as K-means clustering algorithm, to perform clustering analysis on color data. By adjusting clustering parameters and optimizing clustering performance, ensure that colors in the same category have similarity, while colors in different categories have differences. Evaluate the clustering results to ensure their accuracy and effectiveness.

Clustering algorithms typically group based on the similarity of color features such as hue, brightness, saturation, etc. Disguising colors with similar color characteristics are visually closer, so they are more likely to be classified together. This similarity measure can be achieved by calculating the Euclidean distance, cosine similarity, or other appropriate distance measures between color features. The classification of camouflage colors also needs to consider the requirements of their application scenarios. Different application scenarios have different requirements for camouflage colors. For example, military camouflage requires attention to concealment and camouflage effects, while product design may focus more on color matching and visual effects. Therefore, when clustering and classification, it is necessary to combine the requirements of application scenarios and classify camouflage colors with similar application characteristics into one category. There are too many types of colors in the camouflage image library, which brings many inconveniences in practical use. In order to better adapt to application scenarios, it is necessary to simplify according to clustering algorithms.

This paper adopted the KMENS function [15] in MATLAB software to classify the functions in the standard color library, and classified them into 5, 8, 10, 12, 15, and 20 categories on the basis of the estimated results. Then, this paper obtained the cluster center coordinates for each category. After clustering, the distance between each sample and the nearest cluster center was summed and the average value was taken to obtain the most cost-effective solution.

2.3. Analysis of Average Color Difference

By calculating the average value of color difference [16] for different types (as exhibited in Table 1), the change rates between the two are 26.51, 16.685, 5.24, 6.93, 3.182, 6.002, and 9.554, respectively.

Table 1. Correspondence between color clustering number and average color difference.

Clustering number	5	8	10	12	15	20	25	30
Color difference	171.15	91.62	58.25	68.72	47.91	32.00	62.01	14.24

As exhibited intuitively in Table 1, the more types of color classification, the smaller the average color difference. Nevertheless, considering the generation cost and practical portability requirements, the clustering method that reduces the average color difference the most when the type changes should be chosen. Next, this article focuses on analyzing the clustering of 5 to 8 colors.

The more colors a camouflage net decorative piece has, the better the effect, but at the same time, it brings greater difficulty in protection and loses convenience. On the contrary, the fewer colors a camouflage net decorative piece has, the more convenient it is to use, but the camouflage effect is relatively poor. Therefore, achieving a balance between the color variety and camouflage effect of the camouflage net decorative film will be a decision-making issue. This article was limited by experimental conditions and selected an appropriate type of camouflage net decorative film.

Same as the previous analysis method, the color of the decorative pieces is most suitable when divided into 6 categories. Aside from that, the coordinates of the cluster center of the clustering are the color information of the required decorative pieces, and the determined decorative piece color information is exhibited in Table 2.

Table 2. Decorative piece color information for 6 colors.

	L	**a**	**b**
Color 1	51	44	34
Color 2	39.1875	-0.6875	-0.6875
Color 3	58.7333	10.1333	28.2

Color 4	43.5625	-14.625	26.875
Color 5	84.25	3.125	6.5
Color 6	64	-6.3333	-10.5666

3. Using decorative pieces based on Computer Vision

Using computer vision to use camouflage net decorative films mainly involves the following steps: first, using a computer vision system to recognize and locate the target object, determining the location and scope of the camouflage net decorative film that needs to be applied. The recognition and localization of disguised targets using computer vision requires capturing images or videos containing disguised targets through cameras or other sensors. Applying image processing techniques such as filtering and edge detection to enhance target features and reduce background interference. Using object detection algorithms, such as convolutional neural networks (CNN) in deep learning, to recognize targets in images. Real time localization of disguised targets in the image through target tracking algorithms. Throughout the process, the algorithm parameters are continuously optimized to improve the accuracy and real-time performance of recognition and localization. Next, using image segmentation and feature extraction techniques, analyze the color, texture, and other features of the target object and its surrounding environment, providing a basis for the selection and design of camouflage net decorative films. Then, based on the analysis results, select suitable camouflage net decorative pieces and apply them to the target object. During this process, computer vision technology can also be used to monitor and adjust the application effect of camouflage net decorative pieces in real-time, to ensure that they can effectively integrate into the surrounding environment and achieve the best camouflage effect. Finally, through the evaluation method of computer vision, the camouflage effect is objectively evaluated, providing reference for subsequent camouflage strategy adjustment and optimization.

3.1. Background Color Extraction

In order to demonstrate the usage process and methods of camouflage net decorative pieces in detail, a typical forest background is selected as the experimental object. In a scene, in order to obtain information about the forest background, background images are collected. Take an optical photo of the background near the target, as exhibited in Figure 1. The color distribution is reflected in the RGB color space using software, as displayed in Figure 2. The extracting results of the RGB, Lab, and area ratio of main colors by adopting software are illustrated in Table 3.

Figure 1. Background optical photo.

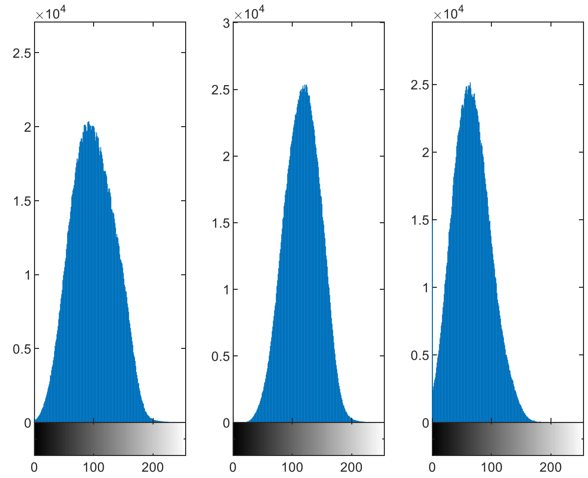

Figure 2. Color distribution histogram of background in RGB color space.

Table 3. Extracted information of 4 main colors.

No.	R	G	B	L	a	b	Area ratio
Main color 1	133.0725	128.4541	91.2574	53	-3	21	26
Main color 2	171.2154	166.1462	130.3521	68	-3	19	38
Main color 3	208.4118	203.3137	169.0269	81	-2	18	25
Main color 4	78.9476	76.0787	40.2166	32	-3	22	7

The results of extracting 5 and 6 main colors of the background through the same method are exhibited in Tables 4 and 5.

Table 4. Extracted information of 5 main colors.

No.	L	a	b	Area ratio
Main color 1	61	-3	20	7
Main color 2	72	-2	19	41
Main color 3	84	-2	18	21
Main color 4	47	-3	21	20
Main color 5	28	-3	21	5

Table 5. Extracted information of 6 main colors.

No.	L	a	b	Area ratio
Main color 1	65	-3	20	26
Main color 2	75	-2	19	23
Main color 3	85	-2	18	11
Main color 4	55	-3	21	19
Main color 5	43	-3	22	8
Main color 6	24	-3	21	2

Based upon the color information of the retrieved camouflage net and the comparison of the average color difference between the extracted background main color and the camouflage net color, this study selected the camouflage net with the smallest color difference to determine the type of camouflage net used. After comparison, the scheme using forest type camouflage net has the smallest total color difference. In view of this, this study will conduct subsequent experiments using the forest type camouflage net.

3.2. Replace Colors in Camouflage Net

To deal with the problem of conspicuous color differences and low fusion between some colors and the background in camouflage net, this study referred to relevant data and determined the camouflage net used. The color area with the greatest difference from the main color of the background was analyzed and obtained, and the decorative pieces with the highest fusion with the background was used to replace the color with the lowest fusion on camouflage net.

This article referred to the forest type camouflage net information, and fuzzily extracted spot colors from left to right as color 1, color 2, color 3, color 4, and color 5. Through calculation, this study found that the spot colors with significant differences in color difference from the background average in camouflage net are color 1, color 2, and color 5. The color difference calculation results are displayed in Table 6.

Table 6. Calculation results of average color difference between each color and background.

Color	Color difference
Color 1	146.10
Color 2	149.25
Color 3	95.63
Color 4	108.05
Color 5	139.09

3.3. The Principle of Fixing Decorative Pieces

Based on the color components that affect the fusion between the target and background in camouflage net, this study determined the category of decorative pieces used and fixed them, then covered and replaced the parts with poor camouflage effect.

It’s noteworthy that the shape of the decorative pieces should match the unique contour of the background spots. Aside from that, the decorative pieces adjacent to the background on the target should match the shape of the background spots as much as possible, making them a continuation of the background spots. In an effort to ensure that the decorative pieces ameliorate the camouflage effect of the camouflage net, the following two requirements should be met as much as possible when decorating the decorative pieces on the target.

(i) The camouflage spots adjacent to the target and background should be fused with the background spots. The camouflage spots on each side of the target that are not adjacent to the background should be able to segment and distort the target, making it an unrelated part of the background. For this reason, a clear brightness contrast must be maintained between the camouflage spots on each side of the target that are not adjacent to the background to prevent obvious interruptions in the spots on the target when the enemy observes from different directions.

(ii) The adjacent spots between the sides of the convex target are interconnected to form a whole, without being separated by the intersection lines of each surface, so as to lower the significance of the turning intersection lines of each surface of the target. Non adjacent spots between each surface should avoid symmetrical configuration to avoid exposing the contours of each side of the target.

(iii) Comparison of methods for fixing decorative pieces

Under actual usage conditions, the fixed time required for decorative pieces is the top priority factor to consider. Considering factors such as cost and portability, three fixing methods were pre-determined, namely spring hook, strap, and Velcro (as displayed in Figure 3), with the effects exhibited in Figure 4 (a), (b), and (c).

Figure 3. Selected three types of fixed equipment.

(a) (b) (c)

Figure 4. Three Fixed Effects.

Based on the applicable conditions of the decorative pieces on the camouflage net, this study analyzed the characteristics of three fixation methods. As illustrated in Table 7, the spring hook has high fixation efficiency and easy operation, but the metal has strong reflection and is easy to rust and fall off; The strap fixation is easy to operate, but the bearing limit is small, and the bearing capacity is small and aging is fast in the outdoor environment; Velcro fixation is simple and fast, but it has the smallest load-bearing capacity and the performance is greatly affected by the environment. The operation time is exhibited in Figures 5, 6, and 7.

Table 7. Advantages and disadvantages of different fixation methods.

Methods	**Advantages**	**Disadvantages**
Spring hook	High fixation efficiency and easy operation	Large weight, strong reflection, and easy to rust and fall off
Strap	Easy to fix and operate	Less bearing capacity and faster aging
Velcro	Easy and fast fixed operation	Minimal bearing capacity, performance greatly affected by the environment

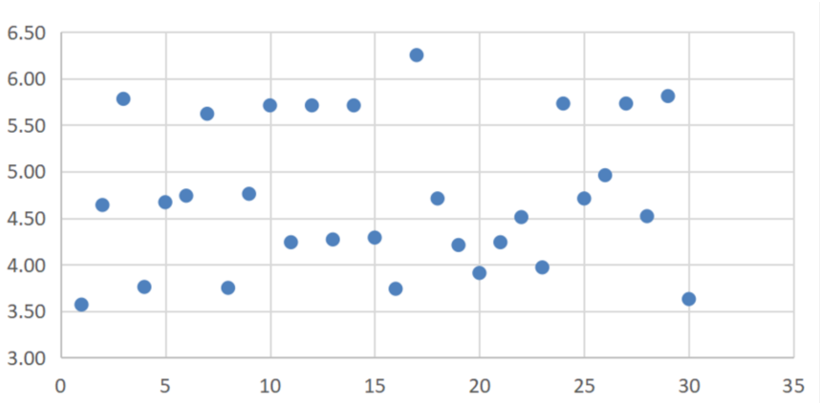

Figure 5. Result chart of spring hook operation time.

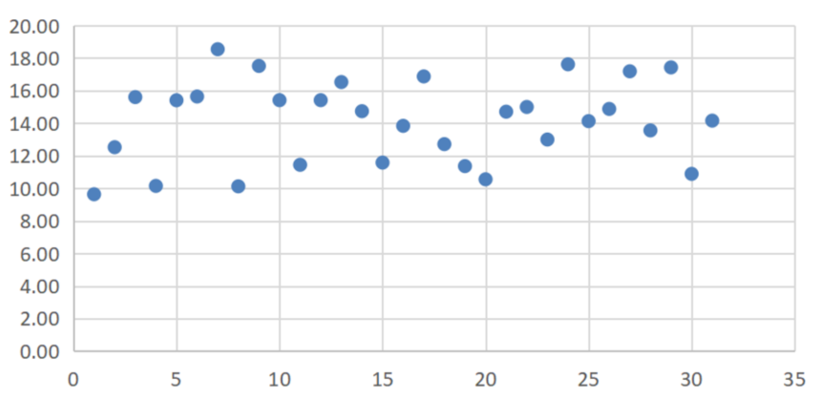

Figure 6. Result chart of strap operation time.

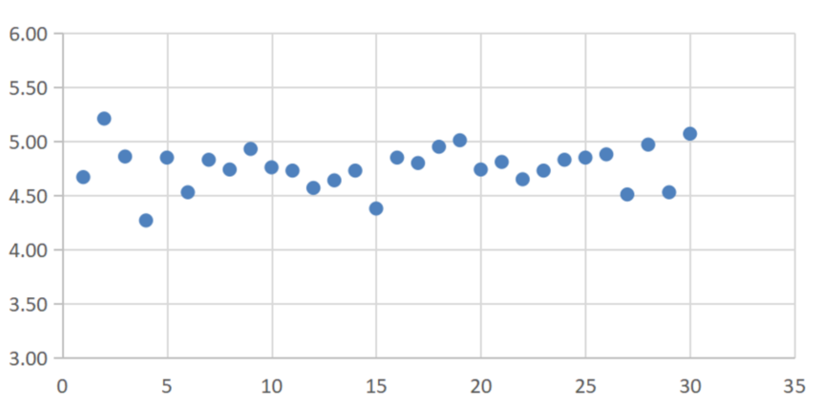

Figure 7. Result chart of velcro operation time.

In line with the scatter plots obtained from the experiments for each fixed method, the confidence interval of each scatter plot is 0.9. The operating time for the three fixed methods mentioned above is: spring hook: 3.57-6.25s, strap: 9.64-18.54s, and Velcro: 4.27-5.21s.

In accordance with the analysis of the operation time span, the operation time interval of the spring hook and Velcro is similar, and the tying operation method takes longer time than the two. Compared with spring hooks, the operating time distribution of Velcro is relatively concentrated, and the range (L) is 0.94 seconds. Considering the characteristics of tight operation time, low fault tolerance, and significant exposure symptoms, among the three fixation methods, Velcro is the best, followed by spring hook, and strap is the worst.

4. Conclusion

The use of computer vision technology can improve the efficiency of camouflage effect evaluation. This topic puts forward a method to heighten the effectiveness of camouflage net by adopting decorative pieces on the camouflage net, including preliminary experimental validation, determination of decorative pieces types and colors, and the use of decorative pieces. By adopting image analysis and design experiments to detect the effectiveness of decorative pieces, it has been proven that decorative pieces have a significant effect on improving the fusion degree of targets and backgrounds, which can further ameliorate the performance of camouflage net. The use of camouflage net decorative pieces can definitely increase the adaptability of the camouflage net surface to the background and improve the camouflage effect. However, the forms of camouflage net decorative pieces can be diverse, and there may also be more effective ways to fix the decorative pieces. The specific use may depend on the environment and available resources. The use of camouflage net decorative pieces can effectively improve the camouflage effect of the camouflage net. The more types of decorative pieces there are, the better the effect, but the more equipment needed to be carried. Here, 6 colors were selected for the experiment, and a forest type background was selected for the experiment. The order of replacement was determined by sorting the color difference between the camouflage net and the background color. Three colors with a color difference greater than 139 were selected for replacement. And three fixed methods of homework time were tested, with a pattern pasting time of 4-6 seconds, which is the most convenient to use.

Looking ahead to the future, using computer vision methods to improve the camouflage effect of decorative films will become an important development direction. With the continuous progress and innovation of computer vision technology, we can expect the emergence of more intelligent and automated methods for enhancing camouflage effects. For example, through deep learning techniques, we can train more accurate models for evaluating camouflage effects, achieving automated analysis and optimization of camouflage effects. In addition, computer vision can also be combined with advanced technologies such as 3D printing and flexible materials to promote innovation in decorative film design and production, further enhancing camouflage effects. Meanwhile, with the development of multi-sensor fusion technology, we can combine computer vision with other sensors (such as infrared, radar, etc.) to achieve all-round and multimodal camouflage effect evaluation and improvement. In summary, the development of computer vision technology will provide strong support for improving the camouflage effect of decorative films, and promote camouflage technology to constantly reach new heights.

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