Digital Camouflage Design Algorithm Based on Template Combinatorial Optimization

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Abstract

In order to improve the camouflage performance of digital camouflage textures, a digital camouflage design algorithm based on template combinatorial optimization is proposed to overcome the shortcomings of digital camouflage. Firstly, according to the common digital camouflage textures, the digital camouflage template library is constructed, and then the main color is extracted from the background image as the basis to determine the camouflage color of the designed digital camouflage. Then, based on the camouflage pattern of digital camouflage, a new distribution algorithm of spot templates based on greedy algorithm is proposed. At last, the digital camouflage pattern is generated by the patch pattern distribution optimization algorithm based on greedy algorithm. The simulation results show that the digital camouflage design algorithm based on template combination optimization is more camouflage than the common digital camouflage textures.

Key words: Digital Camo; Texture Design; Spot Template Library; Shape Constraint; Greedy Algorithm; Combined Template Optimization

1. INTRODUCTION

With the emergence of digital camo, the level of camouflage technology has been improved (Lin, Chen, and Gao et al., 2009). Though the real efficiency has been good, digital camo as the most important and common technique among camouflage technology need to be elevated reasonably and scientifically so that it can develop constantly (Lin, Jin and Talbot, 2002). As the old saying goes, "a workman who wants to perfect his work sharpens his tools first". Systematic and proper digital numerical design is important to digital camo technology (Slaw Wesolkowski and Paul Fieguth, 2013).

We set target design as the hot research directions of camouflage design research. For example, Narek Pezeshkian and others (Fezehkian and Neff, 2012) make use of the camera which is loaded on the device to collect background sample, according to which they compound images of large scale to achieve the purpose of camouflage. This method is particularly for detecting robot on the battlefield. The domestic researchers have conducted many researches on improving the quality of camouflage images. Among which Lu Xuliang and others (Troscianko, Benton and Lovell, 2009) have analyzed the detecting threat of the targets camouflage, and from the perspective of resolution ratio of human beings, they conduct research on the shape and size of the camouflage spots. Liu Yimin (Lin, Chang and Liu, 2014) analyzes the characteristics of camouflage and point out the advantages of small-spot camo. They gave account of the mixing rules and metamerism and put forward the initial project of setting up the small-spot camo. Zhang Yong(Joseph, Malm and Zakel, 2007), targeting at the difficult problem of camouflage design, puts forward the concept of bionic camouflage pattern, bringing the information of biological characteristics into traditional camouflage design principle. They expounded the method of bionic camouflage, designing four kinds of bionic camouflages and evaluated the effect of them. Besides, there are many experts who make use of computer vision technology to improve the quality of camouflage image. They also design the camouflage from different aspects and gain improvements in the quality of camouflage. However, there is still scope in matching quality of camouflage image and the background and the efficiency of the camouflage image (Zhou et al., 2004). Hence, this kind of method is relative effective and practical technological route to optimize the quality of device and improve generating efficiency, which is also the hot-spot of army camouflage research.

In this paper, a digital camouflage design algorithm based on template combination optimization is proposed, which is based on the defects of the common texture pattern of digital camouflage, and its simulation is carried out to verify the effectiveness of the improved method.

2. DIGITAL CAMOUFLAGE EXTRACTION ON THE BASIS OF CONSTRAINT

To achieve better camouflage effect, the digital camouflage need satisfy such constraints: (1) the digital camouflage should contain at least two colors with different brightness coefficient. Then the two spots segmentation with high contrast can be used to destroy the initial condition of the mock object; (2) the brightness of camouflage cannot go far from the background. It is better lower than the brightness of the

background. The camouflage that satisfy the constraints above can help elevate the favorable performance of the camouflage image. Hence, the paper when using clustering method to extract the background color, has combined the constraints above to select digital camouflage. The process of extraction is shown as picture1.
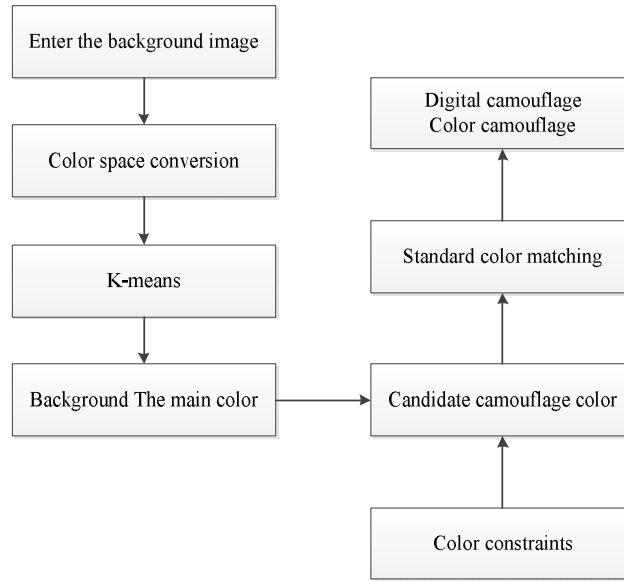
Figure 1. Digital camouflage color extraction flow chart

(1) Color space conversion. The paper select HSV space which is consistent with human visual system. At first, it transfers the background image of RGB space into HSV space.

(2) Clustering. The paper uses K HBFCM when extracting the background color and conduct clustering on them. Finally it gains k kinds, of which the averaged value can represent each kind. It sets the representative color as k background colors. And preserve the quantities of each pixel.

(3) According to this, we select n candidate camouflage ($n < k$). The paper defines the brightness contrast i and j as such equation:

$$vd(i,j) = \frac{|v(i) - v(j)|}{\max(v(i), v(j))} \tag{1}$$

First of all, according to the quantities c_i of pixel in background color MC_i, we set it in descending order. Then we select background color MC_i as candidate camouflage CC_i :

$$vd(MC_i, bgcolor) < d1 \tag{2}$$

Among which, $d1$ is the setting threshold value, $bgcolor$ is averaged background color, the brightness of which is of averaged brightness. Among n candidate camouflage, if there exist two camouflage MC_i and MC_j which satisfy the equation, then it can move to step 4. If not, we remove the last candidate CC_n and select one whose brightness contrast is bigger than $d2$ as the last candidate camouflage CC_n.

$$vd(MC_i, MC_j) > d2 \tag{3}$$

After determining the camouflage $\{CC_i \mid i = 1, 2, ..., n\}$, we record the proportion P_i of each candidate camouflage, and set is as the principle of other design. Among which, can be calculated as the equation followed:

$$P_i = \frac{c_i}{\sum_1^n c_i} \tag{4}$$

Among which, c_i is the quantity of pixel in corresponding background color i of camouflage CC_i.

(4) To decided whether it is matching with military standardized color, if not, we set n candidate camouflage as that of digital camouflage; if is, move to step 5.

(5) Calculate the Euclidean distance between n candidate digital camouflage and military standardized color, select the latest one to replace the candidate one.

Finally we gain digital camouflage $\{DC_i \mid i = 1, 2, ..., n\}$ and its proportion.

3. BUILDING DIGITAL CAMOUFLAGE SPOT TEMPLATE LIBRARY

When designing camouflage images, the paper divides the template into kinds according to the functions of each spot template. One is big-spot template, whose function is to compose the major shape and function to destroy the initial target; the other is modifying spot template, whose spot is smaller and the distribution of its pixel is separated. Picture 2 is followed.
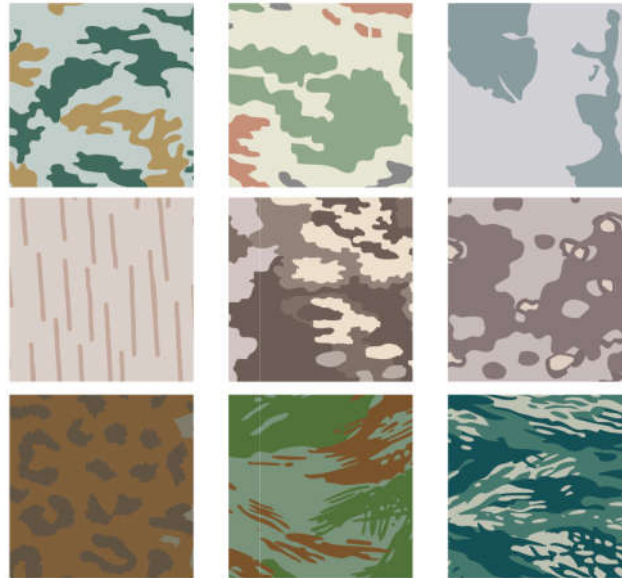

Figure 2. Camouflage pattern template

4. DISTRIBUTION AND COMBINATION OF THE DIGITAL CAMOUFLAGE SPOTS

4.1. Shape Constraints of Digital Camouflage Spots

To improve the favorable performance of digital camouflage, we should not only demand the matching between camouflage and the background but also the background texture and the spot so that it can be easier to avoid detection. To acquire better optical camouflage effect, the distribution of camouflage spot should satisfy such constraints:

(1) Targeting shape destroying constraints: the camouflage must well segment the shape of the targets, which means the camouflage generated by spot template combination should at least contain two major spots with big brightness contrast to destroy the whole shape of the targets so that camouflage can be achieved.

(2) No-rule constraint: the shape of the spots is irregular, there is no large color piece and longer stripe.

(3) Hierarchy: around large spots, put some same-color modifying spots and big-contrast different-color modifying spot, which can make the camouflage more hierarchical and more close to real scenes so the image is more confusing.

(4) Efficiency constraints: to improve productivity efficiency and save camouflage coating and productivity cost, it better satisfies the three steps above and, at the same time, it should avoid the repeating of camouflage spot template so that the final-period cost can be saved.

4.2. Distribution and Optimization Based on Spot Template Optimization

The optimal pricing measures this paper has applied is the quantifiable outcomes of digital camouflage shaping constraint. The distribution of spot is irregular, but the constraints condition of distribution lead the distribution like multiple powers and determine the distribution of the spots. The more it meets the demand, the smaller the cost is; otherwise, the cost is bigger. In the process of generation of camouflage, the distribution of camouflage can change the cost of generating the next distribution template. The paper sets the cost P as the optimal pricing measures of the algorithm.

First of all, we set cost graph, among which the value of each pixel represents the air brushing cost that the pixel has costed, the initial value is 0. From the constraints condition we can see that the template is better not over-matching of connecting or it will leads to lavish of large same-color area and coating.

In the paper, each template of the camouflage library is preserved in the computer as a form of 0-1matrix, among which, 0 represents blank area; 1 represents the covering area. Set one template for example, the spot template matrix T_i is shown as picture3.

0	0	0	0	0	0	0	0	0	0	0
0	1	1	0	0	0	0	0	0	0	0
0	1	1	0	0	1	1	1	1	0	0
0	1	1	1	1	1	1	1	1	1	0
0	0	1	1	1	1	1	1	1	1	1
0	0	0	1	1	1	1	0	1	1	1
0	0	0	1	1	1	1	0	0	0	1
0	0	1	1	1	1	1	1	1	0	0
0	0	1	1	1	0	1	1	0	0	0
0	0	1	1	0	0	1	1	0	0	0
0	0	0	0	0	0	0	0	0	0	0

Figure 3. Example of a spot template matrix

The distribution of template can be covered the cost value C, the paper assumes that every distribution will lead to upping value e. Hence, the template in digital camouflage library should be corresponding with one cost matrix TC_i, then the cost matrix is shown as picture4.

0	0	0	0	0	0	0	0	0	0	0
0	e	e	0	0	0	0	0	0	0	0
0	e	e	0	0	e	e	e	e	0	0
0	e	e	e	e	e	e	e	e	e	0
0	0	e	e	e	e	e	e	e	e	e
0	0	0	e	e	e	e	0	e	e	e
0	0	0	e	e	e	e	0	0	0	e
0	0	e	e	e	e	e	e	e	0	0
0	0	e	e	e	0	e	e	0	0	0
0	0	e	e	0	0	e	e	0	0	0
0	0	0	0	0	0	0	0	0	0	0

Figure 4. The Distribution Matrix Cost Matrix

In the digital camouflage, we set (x, y) as the spot template i, for pixel (x, y) in neighborhood $m \times n$, the distribution cost $MC(x+g, y+h)$ of pixel points $(x+g, y+h)$ is calculated as equation(5) and the cost graph is as followed:

$$MC(x+g, y+h) = MC(x+g, y+h) + TC_i\left(\frac{m+1}{2}+g, \frac{n+1}{2}+h\right) \tag{5}$$

Among which,

$$\frac{-(m-1)}{2} \leq g \leq \frac{m-1}{2} \tag{6}$$

$$\frac{-(n-1)}{2} \leq h \leq \frac{n-1}{2} \tag{7}$$

The optimal pricing measure is the cost generated in the current spot template. The value $P_i(x, y)$ of some pixel (x, y) is set as the center; the template matrix of spot template is the convolution kernel.

The paper sets P as optimal pricing measures, combining the idea of constraint and greedy algorithm, putting forward a spot template distribution algorithm on the basis of greedy algorithm. The concrete process of the algorithm is as followed:

(1) Initialization: making use of the color with largest proportion to coat the background color. Set a cost graph and MC distribution, set the initial value as 0.

(2) The coat of the major shape: we define coordinate system in the camouflage image, selecting s random curves and $N1$ as the nakaya position of the major-spot template. Among the $N1$ points, we select major colors according to color proportion. We randomly choose a digital camouflage big-spot template to coat. And in the process of coating, we cover the change of cost value MC so that the major shape of the camouflage image can be sketched to destroy the constraints of initial targets.

(3) On the distribution of digital camouflage image we make use of greedy algorithm. When selecting the current optimal distribution we should according to the value of P. The optimal template distribution owns the lowest cost. So each time we should choose the lowest value of P as the center of the template, then the cost can be reduced step by step. The optimal distribution can reduce the distribution cost effectively and finally approach the lowest value. The main content includes the steps as followed:

1) Select template color according to the subject color c;

2) Select the main template i randomly and gain template matrix T_i;

3) Greedy selection: we acquire maximum connected domain D in the camouflage, we get P_i and find the minimum pixel point (x, y).

4) If the selected template color c is the same as that of the connected domain D, then we randomly select another color as the template color.

5) If set the pixel point (x, y) as template i, the color c should be distributed in template, which means the value of pixel in the covering area should be changed into c.

(4) We look for the biggest connected domain D_{max}, if $D_{max} > D$, then we revert to step (3), otherwise we move to (5).

(5) Modifying of camouflage image: we look for bigger camouflage spot among the camouflage image. Repeat the steps above twice so make sure that the camouflage image have good hierarchy.

5. ANALYSIS OF INSTANCE SIMULATION

To prove the efficiency of this optimized algorithm, we carry out simulated examination.

5.1. Image Design of Digital Camouflage

On the basis of the digital spot camouflage library the paper has established, we make use of digital camouflage algorithm to design digital camouflage texture, the result is shown as picture 5.
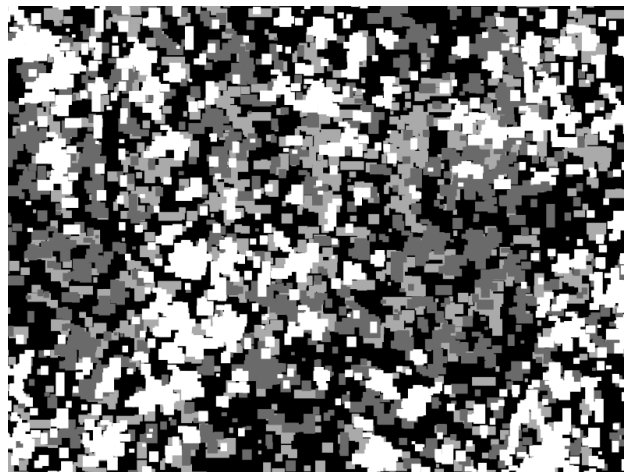

Figure 5. Digital camouflage design structure

From the picture we can see that, the marginal spot is unclear, presenting irregular shapes and is easier to fading color. Besides, we can see that in some large spots there are distributed small different-color spots, which makes the whole camouflage image more hierarchic from the real background. The favorable performance can be better.

5.2. Real Surrounding Test of Digital Camouflage

To go to deep to test the performance of digital camouflage texture, we set four different scenes for example, the result is shown as picture 6-9.

Figure 6. Scene 1's camouflage effect

Figure 7. Scene 2 of the camouflage effect

Figure 8. Scene 3 of the camouflage effect

Figure.9 Scene 4 of the camouflage effect

From the results above we can see that, by using the digital camouflage texture this paper has devised, the targets can be better disguised, which proves that the digital camouflage texture has better favorable performance.

6. CONCLUSIONS

Camouflage can reduce the probability of military targets, which indirectly improve the probability of living. Therefore, as one of the disguising ways, camouflage is indispensable in confronting investigation. Quantities of facts have proved that camouflage makes a big difference in the battlefield. Hence, many countries have conducted wide and deep research in camouflage technology. The paper targets at the deficiency of common camouflage texture, putting forward an optimized combined template camouflage algorithm. The instance simulated experiment proves that in comparison with the traditional camouflage, this optimized method has better favorable performance.

REFERENCES

Caro T (2015) "The adaptive significance of coloration in mammals", *Bioscience*, 55(2), pp.125-136.

Fezehkian N, Neff J D (2012) "Adaptive electronic camouflage using texture synthesis", *Proceedings of the SPIE - The International Society for Optical Engineering*, pp.8707-8707.

Foss C F(2005) "UK Armoured vehicles get thermal imaging", *Jane's Defense Weekly*, 42(1), pp.11-11.

Jianping Fan, K. David (2010) "Automatic Image Segmeniation by Integrating Color-Edge Extraction and Seeded Region Growing", *IEEE Transactions on Image Processing*, 10(10), pp.154-160.

Joseph. B., Malm. Andrew, Zakel. Andrew, et al. (2007) "High-resolution 3D coherent laser radar imaging", *Proceedings of the SPIE-The International Society for Optical Engineering,* 6550, pp.277-283.

Lin Wei, Chen Yuhua, Gao Hongsheng, et al.(2009) "Detection probability evaluation model based on texture feature of thermal infrared", *Infrared and Laser Engineering*, 38(1), pp.1-5.

Lin C J, Chang C C, Liu B S (2014) "Developing and Evaluating a Target-Background Similarity Metric for Camouflage Detection", *PloS One*, 9(2), pp. 87310-87310.

Slaw Wesolkowski, Paul Fieguth (2013) "Color Image Segmeniation Using Connected Regions", *IEEE Transactions on Image Processing*, 10(10), pp.93-101.

Troscianko T, Benton C P, Lovell P G, et al. (2009) "Camouflage and visual perception", *Philosophical Transactions of the Royal Society B: Biological Sciences,* 364(1516), pp.449-461.

Wang Zhou, Bovik AC, Sheikh H R, et al. (2004). "Image Quality Assessment: From Error Visibility to Stmctral Similarity", *IEEE Transactions on Image Processing*, 13(4), pp.600-612.

Wu Q, Yu Y (2014) "Feature matching and deformation for texture synthesis", *ACM Transactions on Graphics'*, 23(3), pp.364-367.

Zheng Lin, Jesse Jin, Hugues Talbot (2002) "Unseeded region growing for color image segmentation", *Journal of Trauma* , 24(11), pp.938-945.