International Journal of Multimedia and Ubiquitous Engineering
Vol.10, No.6 (2015), pp.159-164
http://dx.doi.org/10.14257/ijmue.2015.10.6.16

# A Digital Camouflage Generation Algorithm Using Color Similarity

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***Abstract***

*A novel digital camouflage generation scheme based on color quantization is proposed. First, a color similarity measurement in RGB color space is presented by exploiting the similarity of two color vectors. Then main colors in the background of the host image are extracted by combining color similarity and color quantization. Finally, the camouflage image is generated by replacing target pixels with main background colors. Simulated experiments prove that the proposed algorithm can achieve full fusion of the target and the background, and the generated camouflage image has satisfactory visual quality.*

***Keywords:*** *Digital camouflage; Color similarity; Main colors extraction; Color quantization*

## 1. Introduction

Traditional optical camouflage has been extensively developed and used during the World War II, which causes a form of cognitive illusions by covering an object with something that projects the scene directly behind that object [1, 2]. Nowadays, the computer aided digital camouflage design has received more attractions than optical camouflage due to the rapid development of information technology. Digital camouflage is the process of concealing the foreground target into the background by irregular pixel substitution, and it can obtain high quality fusion of the target and the background. It is not easy to create satisfactory a camouflage image, which is commonly done by skilled artists [3]. Recently, increasing researchers pay their attentions to digital camouflage design, and employ mathematical methods to generate camouflage images [4-7]. Du et al. designed a digital camouflage image creation approach based on two-scale decomposition [4], which generates camouflage images by coefficients blending in the large-scale layer of the background and the structure layer of the foreground object respectively. Subsequently, Du and Shuang presented a camouflage image generation method by using mean value interpolation and alpha blending operation [5]. But these two camouflage scheme create camouflage image using blending operation rather than mosaic operation, and it is hard to utilize in military field. Yu and Shuang proposed a camouflage images generation method [6], which converted the RGB color space of the background into the Lab color space and extracted main colors using the K-means clustering. Yu and Hu presented a new digital camouflage pattern generation scheme by quantizing the background color, and extracting main colors [7]. These camouflage algorithms did not take full advantage of perception features of host images. To yield visually pleasing camouflage images, a digital camouflage algorithm is proposed in this paper by exploiting color similarity in RGB color

ISSN: 1975-0080 IJMUE

space, which extracts main background colors using color similarity [8] and color quantization, and yields the camouflage image using adaptive pixel substitution.

## 2. Digital Camouflage Generation Scheme Using Color Similarity

The camouflage design aims at hiding foreground target by the full fusion of the target and the background area. The design of digital camouflage should exploit fully the background information. Main colors extraction and camouflage image generation are the two main steps of digital camouflage design as shown in Figure. 1.

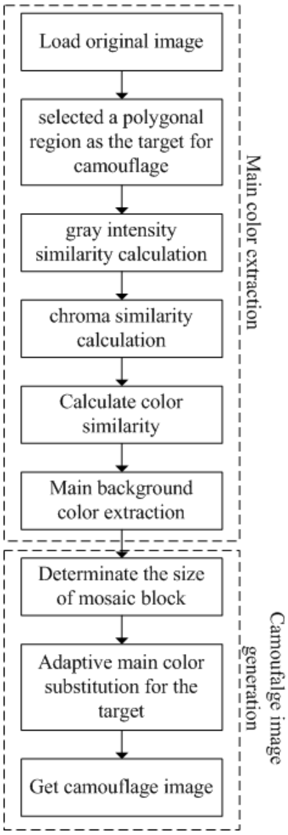



**Figure 1. Block Diagram of Digital Camouflage Design**

### 2.1. Main Colors Extraction Based on Color Quantization

The main colors should be extracted from the background before create camouflage target. The detailed process of main colors extraction is described as follows.

Step 1. Input original image file and get image data I.

Step 2. The user selected a polygonal region via mouse operations as the target region for camouflage, and the image I is divided into two parts: the target and the background.

Step 3. Compute the gray intensity similarity ( $si$ ) of every color C with vector $(r,g,b)$ relative to the known color $C_0$ with vector $(255,255,255)$ as described in Eq.(1).

$$si = \frac{|C|}{|C_0|} = \frac{\sqrt{r^2+g^2+b^2}}{\sqrt{255^2+255^2+255^2}} = \frac{\sqrt{\left(r^2+g^2+b^2\right)/3}}{255}. \tag{1}$$

Step 4. Compute the chroma similarity ( $sh$ ) of every pixel relative to the given color $C_0$ as shown in Eq.(2).

$$sh = \begin{cases} \frac{C \bullet C_0}{|C||C_0|} = \frac{255r + 255g + 255b}{\sqrt{r^2+g^2+b^2}\sqrt{255^2+255^2+255^2}} \\ \qquad = \frac{r+g+b}{\sqrt{3\left(r^2+g^2+b^2\right)}} & if \ \left(r+g+b\right) \neq 0 \ . \\ 0 & else \end{cases} \tag{2}$$

Where $C \bullet C_0$ is the inner production of two vectors C and $C_0$.

Step 5. The final color similarity ($sc$) can be obtained by combining the chroma and the gray intensity, and it can be written as

$$sc = \lambda \times sh + (1-\lambda) si \ . \tag{3}$$

Usually the parameter $\lambda$ falls in range $(0.5,1)$ since the hue and saturation components are main perception features, in the experiments, parameter $\lambda$ is set to 0.80.

Step 6. Extract main background colors using color quantization based on color similarity.

(1) Given parameter $\Delta$ (e.g. $\Delta = \frac{1}{300}$), and divide the whole color similarity range into many bins with interval width $\Delta$.

(2) Find out the bin into which the color of each pixel in the background falls in terms of color similarity. Given any pixel x with color similarity $sc_x$, the bin can be found as depicted in Eq.(4).

$$pixel \ x \in bin_i, i = \left\lfloor \frac{sc_x}{\Delta} \right\rfloor . \tag{4}$$

Where $bin_i$ is the interval $\left[i \times \Delta, (\mathrm{i}+1) \times \Delta\right)$.

(3) Define a integer array A with initial value 0, that is, $A[i] = 0, \mathrm{i} = 0,1,2\cdots,n-1$.

(4) Count the numbers of pixels which falls into in each color similarity bin for all pixels in the background, and store the numbers into array A.

$$A[i] = \begin{cases} A[i]+1 & if \ pixel \ falls \, into \, bin_i \\ A[i] & else \end{cases} \tag{5}$$

(5) Given the number k of main background colors, search for the first k bins with maximum pixel numbers from array A, and use the colors with maximum color similarity in the k bins as main background colors.

## 2.2. Camouflage Image Generation

To obtain pleasing camouflage target, during the process of generating the camouflage image, the target pixel should be proportionally substituted by main colors. The detailed camouflage creation process is as follows.

Step 1. If the viewing angle is less than 1 cent (about 0.0167°), then the vanishing point is farther away from the line of vision. So, the size ($L \times L$) of mosaic block can be calculated by the combination of the image resolution R, engineering scale S and observer distance D using

$$L = \left\lfloor D \times R \times S \times 39.37 \times \tan 0.0167^{\circ} \right\rfloor \tag{6}$$

Where the operator $\lfloor x \rfloor$ returns the largest integer that does not exceed x. For example, assume R=600 dpi, S=1/300, D=300 m, then $L \le 6$.

Step 2. Create k main color blocks with size $L \times L$ using main colors extracted from the background.

Step 3. Obtain the proportion of each main color, and replace the target pixel blocks with main color blocks proportionally.

Step 4. Apply the combination of mathematical morphology operations to the preliminary camouflage image, and finally a visually pleasing camouflage image is generated.

## 3. Simulated Experiments

This camouflage scheme is implemented under Matlab12.0, and is tested under some different types of images. Two test images with different types were selected as a case study to test the proposed digital camouflage pattern design, and shown in Figure 2. One can choose a polygonal region as the target region (*e.g.* the tanker) as shown in Figure 2, and the other part of the original image is denoted as the background region.

(a) Test Image 1 (b) Test Image 2

**Figure 2. Original Test Images**

Figure 3 illustrates the extracted main background colors combining color similarity from test image in Figure. 2 (in the experiment, the number k of main background colors is set to 3). It can be seen that these extracted colors can reflect the dominant hue very well because of the considering of visual perception.

(a) Main Colors of Test Image 1 (b) Main Colors of Test Image 2

**Figure 3. Main Background Colors Extraction**

Figure 4 shows the generation of the digital camouflage pattern. (a), (b) are the camouflage images generated by adaptive main color substitution. (c), (d) are the further modified digital camouflage pattern by morphological operations.

(a) Camouflage 1 (b) Camouflage 2

(c) Modified Camouflage 1 (d) Modified Camouflage 2

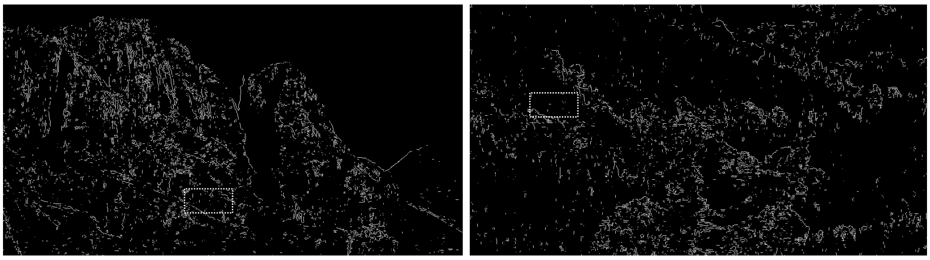
**Figure 4. Generation of Camouflage Images**

From Figure 4, one can observed that the camouflage colors in the object area are very near to dominant background colors. Moreover, the generated camouflages have high PSNR values above 18.80 dB as listed in Table 1, and the visual quality of them is pleasing. So, the proposed camouflage design scheme can reduce significance of the object in camouflage images.

**Table 1. PSNR Values of Camouflage Images (dB)**

| | Camouflage image 1 | Camouflage image 2 |
|---|---|---|
| PSNR | 18.8419 | 21.4130 |

In addition, the camouflage effect of the camouflaged target is further tested through image edge detection. Figure 5 shows the edge detection results of camouflaged targets in different background with prewitt detector. As seen in Figure 5, since the colors of camouflaged targets have much more similarities with the surroundings, and the camouflage design can achieve a satisfactory fusion of the target and its surroundings, it is difficult to recognize the camouflaged targets in camouflage images. The proposed camouflage scheme can produce camouflage images with high visual quality.



(a) Edge detection of Camouflage Image 1(b) Edge Detection of Camouflage image 2

**Figure 5. Camouflage Effect of the Proposed Camouflage Design Scheme**

## 4. Conclusions

The paper presented a new digital camouflage design scheme by exploiting the color similarity. An improved color similarity computation method is first used to extract the dominant background colors, and then an adaptive pixel substitution is adopted to obtain the camouflaged target by combining color similarity of the target and its surroundings. Simulated experiments prove that the camouflage algorithm can effectively fuse the target and its background into a cohesive whole, and obtain the camouflage image with high visual quality.

## Acknowledgements

This work was supported in part by the National Natural Science Foundation of China under Grant No. 61073191, 61170287 and 61232016, Key Program of Hunan Provincial Education Department of China under Grant no. 12A029, Soft Science Research Key Program of Hunan Province under Grant no. 2013ZK2014.

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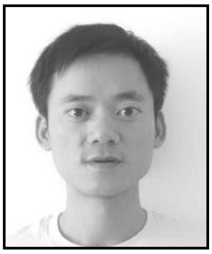

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