Image Tactile Perception with an Improved JSEG Algorithm

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Abstract

Image tactile interaction is a new interaction method between human and digital images, allowing users to know digital images by touch. In order to improve the authenticity of image tactile perception, this paper proposes a tactile perception model based on image region features. Aiming at the phenomenon of over-partitioning and computational complexity of JSEG algorithm, we propose an improved JSEG algorithm, which can effectively reduce the computational complexity, divide the image areas which are more in line with the subjective visual judgment, and can be used for region-based image tactile generation. The experimental results show that the proposed algorithm can correctly distinguish the image area and improve the accuracy of image tactile perception.

Keywords: image segmentation; JSEG; tactile perception

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1. Introduction

Tactile is the only choice for the blind to perceive the external environment. The image information is acquired by the shape of the surface of the object in the tactile perception image, the tactile texture and the softness [6,13]. Through the different tactile characteristics of the different regions of the image in the touch pane, the division of the image area on the touch panel is critical to the rapid and accurate knowledge of the blind [2,15]. Likewise, for digital images, a reasonable area division is the key to the generation of realistic tactics. So it requires the image of the division to not only convey the overall image of information as little as possible, but also to achieve real-time interaction with human-computer interaction [3,9,10].

The regional division of the image is to extract the characteristics of the region. Many algorithms of image regional division have been proposed [1,12,14]. Not all of these algorithms are suitable for the generation of image tactile perception, because it is necessary to not only need a reasonable area division in the image but also to minimize the time complexity of the objects that need to be interacted, to ensure real-time and authenticity of tactile perception [7,8,11].

The region growing method is simple in calculation, and has better segmentation effect for even homing target. However, it is necessary to identify seed points artificially and be sensitive to noise, which may lead to voids in the region. The splitting and merging algorithm has a good effect on the segmentation of complex images, but the algorithm is more complicated and computationally expensive, and the splitting may also destroy the boundary of the region. In the image segmentation based on threshold, the image is affected by uneven illumination, which makes the gray scale transformation of the target area very large; the image segmentation effect is not satisfactory. Semantic image segmentation works well, but requires manual labeling of samples and is more difficult. The use of the existing public data set needs higher hardware requirements.

Taking into account these two aspects, this paper presents an improved JSEG algorithm for the recovery of tactile information of digital images based on reasonable image regions.

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2. JSEG image region division algorithm

JSEG algorithm is based on color information and texture information unsupervised image area division method. The algorithm mainly consists of two steps: color quantization and spatial division [5].

2.1. Color quantization

The quantization of the image color reduces the number of colors in the original color image by PGF (Peer Group Filtering) and VQ (Vector Quantization)[4], which facilitates to merge regions. Firstly, the color image is de-noised and smoothed by PGF algorithm; then, the VQ method is used to initialize the color. Finally, the GLA (Generalized Lloyd Algorithm) algorithm is used to cluster the quantized colors.

2.1.1. Image preprocessing

First, the JSEG algorithm converts the original color image to LUV format. LUV is a uniform color space that relatively ideal color description model, so it is the algorithm selected in this color space. PGF filtering is divided into two main steps:

1) Identify the same group of members

In an image of size $W \times W$, first calculate the distance between the center pixel of the filter window $\omega \times \omega$ and the color of each neighborhood pixel. Let $P_0(x, y)$ be the color value of the center pixel (x, y) , $P_i(x, y)$ $i = 0, \dots, k = \omega^2 - 1$ be the other pixel color value, $d_i(x, y)$ be the color distance between $P_0(x, y)$ and $P_i(x, y)$. Calculated as:

$$d_i(x, y) = \|P_0(x, y) - P_i(x, y)\|, i = 0, \dots, k = \omega^2 - 1 \quad (1)$$

Then ascending order $d_i(x, y)$:

$$d_0(x, y) \leq d_1(x, y) \leq d_2(x, y) \leq \dots \leq d_k(x, y) \quad (2)$$

Next, determine the same group of pixel members. The same group of pixels includes pixels similar to their colors. The number of its members set to s ; the same group of $M(x, y)$ pixels is defined as:

$$M(x, y) = \{P_m(x, y), m = 1, 2, \dots, s - 1\} \quad (3)$$

2) De-noising and smoothing

In order to avoid the impact of noise, the image is de-noised before determining the same group of member pixels. The noise is determined by $d_i(x, y)$ obtained by formula (1):

$$d_{i+1}(x, y) - d_i(x, y) \succ \alpha \quad (4)$$

The value of α is set to 12. If the equation (4) is satisfied, it is determined that the noise point is removed, and in the remaining pixels is determined the same group of members of the pixel.

Finally, the weighted values of the pixels of the same group of pixels are re-assigned to the central pixel, and the image is smoothed to complete the filtering operation.

2.1.2. Color quantification

JSEG algorithm in the color quantization process not only analyzes the color space, but also on the color space distribution. Quantify the basic steps as shown in Figure 1.

Figure 1. Color quantization flowchart

1) Determine the pixel weight and the initial color quantization number N

First, the maximum color distance is obtained according to the same group of each pixel obtained in the previous image preprocessing stage:

$$D(x, y) = d_{s-1}(x, y) \quad (5)$$

$D(x, y)$ represents the color space distribution, also reflected in the image of the local area of the color roughness. Next, determine the initial number of colors:

$$N = \beta D_{avg} \quad (6)$$

Where β is 2 and $D_{avg}(x, y)$ is the average of the maximum color distance $D(x, y)$ for each window, indicating the color roughness of the entire image.

2) Merge

After the GLA algorithm iterations are complete, there are many similar color pixels that are distributed and need to be clustered. Merge the color of similar clusters, and get the final color quantization vector table.

After merging, each pixel is identified as the label of the color class, constitute the class diagram. In the class diagram, the value (x, y) for each point represents the position of the pixel within the image. Figure 2 shows two simple class diagrams of three color categories, with different labels characterizing different color classes and representing three simple color categories.

0 0 0 0 0 1 1 1 1	0 1 0 1 0 1 0 1 0
0 0 0 0 0 1 1 1 1	0 2 0 2 0 2 0 2 0
0 0 0 0 0 1 1 1 1	1 2 1 2 1 2 1 2 1
0 0 0 0 1 1 1 1 1	1 0 1 0 1 0 1 0 1
0 0 0 0 1 1 1 1 1	2 0 2 0 2 0 2 0 2
0 0 0 2 2 2 2 2 2	0 1 0 1 0 1 0 1 0
0 0 0 2 2 2 2 2 2	0 2 0 2 0 2 0 2 0
0 0 0 2 2 2 2 2 2	1 2 1 2 1 2 1 2 1
0 0 0 2 2 2 2 2 2	1 0 1 0 1 0 1 0 1

(a) (b)
Figure 2. Class diagrams

2.2. Spatial partition

Spatial division is the use of a certain classification criteria; the image is divided into different areas. The specific process is shown in Figure 3.

Figure 3. Spatial division flow chart

2.2.1. J value calculation

The J value is used as a criterion for the region division of the JSEG algorithm. Its calculation is done on the class diagram. The local J value of each pixel is calculated by the circular template scanning class diagram centered on the pixel, and the composition J is shown. The value of J is expressed as:

$$J = \frac{S_t - S_w}{S_w} \quad (7)$$

S_t represents the sum of the variance values of the M data, M is the number of pixels within the class, and S_w represents the sum of the variance of each class.

Where S_t and S_w are defined as follows:

$$S_t = \sum_{z \in Z} \|z - m\|^2 \quad (8)$$

$$S_w = \sum_{i=1}^c S_i = \sum_{i=1}^c \sum_{z \in Z} \|z - m_i\|^2 \quad (9)$$

z is expressed as a set of M pixels in the class diagram, let $z = (x, y)$, $z \in Z$, then the mean m can be calculated as:

$$m = \frac{1}{M} \sum_{z \in Z} z \quad (10)$$

2.2.2. Scale selection

As already mentioned, the calculation of the local J value is detected by a circular template window at a scale; the size of the scale indicates the size of the selected template window. The size of the template window at different scales is shown in the following Table 1.

Table 1. Window sizes of different scales

scale	Window(pixel)	Sampling (1 / pixel)	Area size(pixel)	Number of seeds (minimum pixel)
1	9×9	1/ (1×1)	64×64	32
2	17×17	1/ (2×2)	128×128	128
3	33×33	1/ (4×4)	56×256	512
4	65×65	1/ (8×8)	512×512	2048

The size of the circular template window used here is the basic window of the smallest scale in the JSEG algorithm, as shown in Figure 4.

Figure 4. Basic window

2.2.3. Regional growth

Since the seed region is the basis for regional growth, it is first necessary to determine the seed point. A threshold T_J is set in the algorithm to determine the local J value less than T_J in the region as the seed point, and T_J is defined as:

$$T_J = u_J + \alpha \sigma_J \quad (11)$$

In order to select more seed points in the area, the value of σ in the algorithm can be selected from $\{-0.6, -0.4, -0.2, 0, 0.2, 0.4\}$. u_J and σ_J represent the mean and variance of the local J values in each region of the image, and there are N pixels in the region i , $J(i)$ is the local J value of each pixel, then u_J and σ_J are defined as follows:

$$u_J = \frac{1}{N} \sum_{i=1}^N J(i) \quad (12)$$

$$\sigma_J = \left(\frac{1}{N} \sum_{i=1}^N (J(i) - u_J)^2 \right)^{\frac{1}{2}} \quad (13)$$

Alternative seed dots are connected in four-way alternative seed regions where the number of pixels is considered to be the seed region if the number of pixels is greater than the minimum number of pixels at the corresponding scale listed in Table 1.

The next is the growth of the seed region. This can be divided into the following steps:

- (1) Remove unlabeled non-seed pixels in the seed region.
- (2) Select the seed point.
- (3) For details and boundary sections, the local J value of the remaining pixels is calculated with a template window at a smaller scale, and the previous step is performed cyclically.
- (4) Grow the remaining unpartitioned pixels with the smallest size of the template window.

2.2.4. Regional consolidation

First, extract the color histogram of all the regions within the image and calculate the distance between each two color histograms, incrementally sort and store. With the color histogram m and n , P is the histogram vector. Their distance is:

$$D_{CH}(m, n) = \|P_m - P_n\| \quad (14)$$

Then, the two regions with the smallest distance are merged, and the distance between the merged area and the color histogram of the other regions is refreshed, sorted and iterated until the minimum distance reaches the upper limit of the threshold and terminates the merge.

3. The improvement of JSEG algorithm

In this paper, the image is divided in order to serve the sense of touch on the region. You can sub-regional expression of the image surface shape of the object. Each of the different regions reflect a different feel: need for inter-regional merging as much as possible, complexity of the algorithm as low as possible. The JSEG partitioning algorithm will have the phenomenon of over-partitioning, and it needs to be improved in the multi-scale template window. Given that the iterative calculation is based on the color cube, the complicated partitioning process and the high complexity of the algorithm, we can make improvements to this. After quantification by color, we use the incremental seed region growth method to form the initial division area on the basis of the class diagram, and eliminate the process of selecting the seeds with the local J value

iteration. The merging process based on the color histogram is replaced by the region merging of the fusion edge contour information, and the termination rule is proposed.

3.1. Algorithm flow

The improved spatial division method takes into account the color and spatial edge information, which can be divided into two parts. First, the initialization of the image area is completed by using an incremental region growing method for color-quantized images. Then, considering the regional color, edge and adjacency, the regional distance is defined, and the similarity regions are merged into different stages to form a rule to stop the region merging until the condition is completed. The flow chart is shown in Figure 5.

Figure 5. Improved algorithm flow chart

3.1.1. The initial division of the image

Based on the JSEG algorithm, we use the algorithm of incremental region growth to complete the initial segmentation of an image. The seed region of the pixel is defined to meet the following conditions:

- (1) The color is the same after quantization.
- (2) Space to form four connected areas, and the area of seed region shall reach a certain proportion of whole image area (according to the difference in the accuracy of the division, the proportion shall be 0.001%, 0.01%, 0.1%).

Pixels that are not in the seed region are assigned to the nearest neighbor region, if it satisfies the independent conditions:

- (1) Constituting four neighborhoods in the pixel space with other new grown seed regions.
- (2) The average distance of these pixels is less than the average distance of seed areas.

(3) Satisfying the proportion conditions of the seed area.

This way, it is possible to form a new seed region, which is more favorable for the discovery of some detail regions, and the algorithm complexity is relatively low compared with JSEG algorithm, which selects the seed area under different multi-scale template matching.

3.1.2. Region merging

1) Calculations of region distance for region merging

The region distance is an important parameter for the region merging, and affects the quality of the region partition. The color, spatial adjacencies and boundaries are considered as important influential factors in regional merge. Therefore, the region distance is redefined in terms of color, adjacency and edge distance. Suppose that there are $|r_i|$ and $|r_j|$ pixels in the region i and region j , respectively, $\vec{u}_i$ and $\vec{u}_j$ denote the color mean of the region i and j respectively, and the color distance D_{ij}^c can be expressed as:

$$D_{ij}^c = \frac{|r_i| \cdot |r_j|}{|r_i| + |r_j|} \|\vec{u}_i - \vec{u}_j\| \quad (15)$$

Based on Canny operator, the edge distance formula is defined as:

$$D_{ij}^e = \frac{1}{|E_{ij}|} \sum_{(k, l \in E_{ij})} \|\vec{X}_k - \vec{X}_l\| \quad (16)$$

Where $|E_{ij}|$ is the number of pixels on the edge of region i and j , $\vec{X}_k$ and $\vec{X}_l$ are the color values of pixel k and pixel l on both sides of the edge. In addition, if region i is adjacent to region j , then we set Δ_{ij} to 1, otherwise $+\infty$. Finally calculate the distance from the area:

$$D_{ij}^r = (D_{ij}^c)^p \cdot (D_{ij}^e)^q \cdot \Delta_{ij} \quad (17)$$

In the process of regional merging, this paper adopts the hierarchical merging strategy, which starts from the smallest area, merges in an incremental way, and adjusts the new regional distance after the merger.

2) Termination rules for regional mergers

Terminating the merger between regions as a key step in the regional merger directly determines if the regional division of the outcome is good or bad. As mentioned in the previous section, the JSEG algorithm uses the termination method of the threshold method. Based on the repeated distance calculation of the color histogram, the selection of the threshold should be adjusted according to the different image. In this paper, we use the concept of color dispersion in the process of color quantization. A new criterion for terminating zone merging is proposed based on the relationship between the loss of color information and the ratio of the number of remaining regions in the process of zone merging to the total number of initial regions. The areas where the colors in the merged area are not uniform and the areas reserved at the time of termination are merged, both of which achieve the best compromise. That is, when the minimum value of $J_1 + k_1$ is obtained, it can be understood that when the merged area is as low as possible, the degree of disunity of the color is the lowest and the merger is stopped.

In this, we extend the concept of intra-class dispersion to the region, and denote the color dispersion of an area within the image with J_w^r . The color dispersion of the whole image is denoted by J_t . K_1 area after the merger of the color dispersion relative to the proportion of J_t where color is not uniform, can be calculated as:

$$J_1 = \frac{\sum_{r=0}^{K_1} J_W^r}{J_t} \quad (18)$$

Then the proportion of the remaining area k_1 is defined as:

$$k_1 = \frac{K - K_1}{K} \quad (19)$$

In order to facilitate the subsequent image tactile perception, we finally use the intra-class dispersion concept. We calculate the color dispersion in the partitioned area and sequentially number the regions according to the order of dispersion.

3) Post-processing phase

When region merging is completed, the post-processing phase is to remove the noise and smooth boundary of the image, and improve the image quality. This paper uses a circular area and 3 pixels distance radius as a mask to expand and corrode the image after division; the final image is obtained.

4. Experimental analysis

4.1. Regional division experiment

In order to validate the improved JSEG algorithm, we develop an image tactile perception system based on the VS2010 platform. Three images (see Figure 6) were tested for the comparisons between the JSEG algorithm and our improved JSEG algorithm.

Figure 6. The framework of cell image classification

Table 2. Time comparisons (unit: s)

Images	JSEG algorithm	Our algorithm	Relative time is reduced
1	16.37	14.56	11%
2	9.88	9.32	5%
3	18.05	16.22	10%
average	14.76	13.37	9%

From the comparisons of three images, we can observe that our improved JSEG algorithm is better at distinguishing the main area of three images, improving the quality of image division relative to the JSEG algorithm. As shown in Figure 6, compared with the original image, the division result of JSEG algorithm is over-partitioned, and the watermark is obvious. Due to the uneven brightness of the surface of the figure divided into more areas, some of the details such as the shadow of the object and the object itself are divided into more levels. However, the results of our improved JSEG algorithm shall be more consistent with the subjective visual. Table 2 lists the time complexity comparisons. This improved JSEG algorithm is more effective than the JSEG algorithm.

4.2. Tactile perception experiments

It is necessary to perform three-dimensional shape restoration of these different regions by touching the image area after division. In this paper, we use the triangular mesh to express image tactile textures, and use PHANTOM Omni device to feedback the image tactile perception.

We used six rigid texture images (See Figure 7) to test the effectiveness of the tactile images. We randomly selected 10 people. In the course of the experiments, the appearance of the image is hidden and the images are randomly arranged. Subjects used PHANTOM Omni device to select the images of their own interaction in six images by sensing the texture, three-dimensional shape, and tactile feedback of the image surface.

Figure 7. Experiments of image tactile perception

Experimental results are shown in Table 3. 10 subjects on the correct rate of image recognition are significantly higher. The experimental results are basically ideal, the wrong judgment is also expected, and the subjects after the end of the experiment indicate that there is a significant difference in the tactile sensation of each region. In addition, the tactile simulation effect is satisfactory.

- We discussed the errors in the experiment. The reason for the error may be:
1. The detailed information generated by the image in the process of 3D reconstruction is imperfect, resulting in errors when touching.
 2. Since the touch of the image is a single touch through the device, there is a difference between the touch and the tactile perception, which leads to failure.
 3. A failure caused by an individual's inconsistency in the ability to identify the touch.

Table 3. Image tactile perception experimental results
(that recognition ✓ correct, × error)

Subjects	(a)	(b)	(c)	(d)	(e)	(f)	Correct rate (%)
1	✓	✓	✓	✓	✓	✓	100
2	✓	✓	✓	✓	✓	✓	100
3	✓	✓	✓	✓	✓	✓	100
4	✓	✓	✓	✓	✓	✓	100
5	×	✓	✓	✓	×	✓	66.67
6	✓	✓	✓	✓	✓	✓	100
7	✓	✓	✓	✓	✓	✓	100
8	✓	✓	✓	✓	✓	✓	100
9	✓	✓	✓	✓	✓	✓	100
10	✓	✓	✓	✓	✓	✓	100
Correct rate (%)	90	100	100	100	90	100	

5. Conclusions

This paper introduces the JSEG algorithm as well as an improvement in the study of tactile perception based on the algorithm. JSEG algorithm is based on the texture of the regional division, and the following study of the impact of tactile perception of the reasons for the same. The algorithm has high quality of the image area, which can provide a good foundation for high quality tactile perception. However, in order to better serve the research of this paper, we propose the improvement of the over-division of the JSEG algorithm itself and the cumbersome operation process. After the construction of the class diagram through the JSEG color quantization, the incremental division of the seed region is used to form the initial division area. We replace the process based on color histogram with integration of spatial edge contours, adjacency and color information and propose a termination rule. Compared with the JSEG algorithm, the improved algorithm can reduce the complexity of the algorithm and ensure the quality of the image area, which makes it more consistent with the subjective visual experience. The improved algorithm can characterize the different regions of the image, and lay a good foundation for the regional image force tactile tactics. However, the robustness of the improved JSEG algorithm needs to be improved, and the related research needs to be further strengthened.

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