

# **A Research of Defogging Algorithm Based on Clustering Segmentation**

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**Abstract.** Under the condition of fog, the images captured by the mobile phone are blurred, because of the scattering effect of the suspended particles in the air. In order to obtain more information about the image, this paper presents an image dehazing algorithm based on K-means clustering, which will firstly transform foggy image color space, extract the luminance component of the image, use k-means clustering algorithm to segment the sky area of the image. The sky region keeps the same brightness and non-sky area are conducted with adaptive histogram equalization. The experimental results show that when the K is 20, the segmentation results are very close to the sky region of the fog image, and the image processing is improved greatly.

## **1 Introduction**

With the popularity of mobile phones is getting higher, more and more people are studying the mobile phone, more and more application software is installed on the phone. People using the phone to take pictures are becoming more and more high frequency. But in foggy conditions, the suspended particles in the atmosphere have a scattering effect on the sunlight, which can cause the image captured by the mobile phone to be blurred, and the contrast will be decreased, especially in some areas where the image details are demanding, such as intelligent monitoring, behavior recognition, forest fire prevention, and intelligent navigation ET. So defog image is a research hotspot in the field of digital image processing in recent years.

At present, research of image defog algorithm has achieved a series of significant results. In article [1], the main algorithms can be divided into 2 categories which are image enhancement algorithm and image restoration algorithm. Image enhancement algorithm is mainly from the subjective aspect by reducing the image blur to improve the image contrast. The main methods of image enhancement include the homomorphism algorithm in article [2], histogram equalization in article [3] and the Retinex in article [4]. Homomorphism algorithm's function is that mainly set up the filter to reduce the high frequency part of the image. Improve the low frequency part of the image to increase the contrast of the image. Histogram equalization is used to adjust the cumulative function of the image grey level and adjust the frequency of the grey level to increase the contrast of the image. Histogram equalization will result in a certain degree less of the details and some areas could be enhanced by mistake. Under some certain assumptions for defog image, image restoration is based primarily on the physical model of atmospheric scattering. In article [5], Tan achieves the purpose of defog through the improvement of the local contrast of the fog image. Although the algorithm in a certain situation can restore the image, it does not accord with the physical model of atmospheric scattering. The assumption in article [6] is that the scattering coefficient of the image is constant within a few kilometres, the partial differential equation is applied to defog image and finally the image dehazing recovery is realized. In article [7], the sky area of the image is on by human-computer interaction method. The scene depth of each pixel point is computed by manually selecting the vanishing point; the image's contrast is enhanced. Finally, image restoration can be delivered. This method needs artificial interaction to select the sky regions and the relatively strong

subjectivity. The defogging result of this method has a good relationship with the sky area and the vanishing point position. In 2009, in article [8], the dark channel knowledge was received by Dr. He who observes more than 5000 pieces of clear image for statistical observation. Results of dark channel prior have a good effect of removing fog. But time calculation complexity of the algorithm is quite large. This algorithm will be failed when there are a lot of white areas in the foggy image.

Aiming at the shortage of the above algorithm, this paper proposes a defogging algorithm based on k-means clustering that extracting the brightness component of the image by converting the image colour space. Depending on the result of cluster segmentation, the maximum K class mean number's location will be selected as the sky area. The sky region maintains the same brightness and non-sky area is conducted with adaptive histogram equalization, and finally the enhanced image is generated.

## 2 Principle of K-Means Cluster

**2.1 The principle.** K class mean algorithm, also called K-means algorithm, divides all the points in the image through the iterative method. By making some criteria of evaluating clustering performance to be optimal, the result of segmentation is compact within the cluster and the clusters are independent of each other.

### 2.1.1 Criteria for selecting similarity metric

In this paper, the Euclidean distance between pixel data is used as the criterion for similarity measurement. The details as follows:

Assuming the initial pixel data is  $X = \{x_m \mid m = 1, 2, 3, \dots\}$ . All pixels are described by D continuous attributes  $A_1, A_2, \dots, A_d$ . The similarity between pixels is measured by the Euclidean distance  $d(x_i, x_j)$  between them. The smaller Euclidean distance is, the larger similarity between those pixels is.

The formulation of Euclidean distance between the pixels is as shown in Eq. (1).

$$d(x_i, x_j) = \sqrt{\sum_{k=1}^d (x_{ik} - x_{jk})^2} \quad (1)$$

In Eq.1,  $x_{ik}$  and  $x_{jk}$  is the specific value of D continuous description of the pixel  $x_i$  and  $x_j$ .

### 2.2.2 Criterion function of clustering performance evaluation

In this paper, the error square sum criterion function is used as the criterion function of the clustering performance evaluation. Assuming that in a given pixel data, only the description of the property is considered in steel of the category attribute. The pixel data contain a K cluster subset, and the formula of the error square sum criterion function is shown as follows in Eq. (2).

$$E = \sum_{i=1}^k \sum_{p \in X_i} \|p - m_i\|^2 \quad (2)$$

In Eq.2, P is the pixel value of a pixel in each cluster,  $m_i$  represents the clustering centre of each cluster.

### 2.2.3 Calculation of similarity

Similarity calculation depends on the mean of all pixels in each cluster. First, all the pixels are allocated to the K cluster in random ways, and calculate the mean of the each cluster at the same time. Then choose the center of each cluster, and calculate the distance between the center and every pixel. All the pixels are assigned again. Specific steps are as follows.

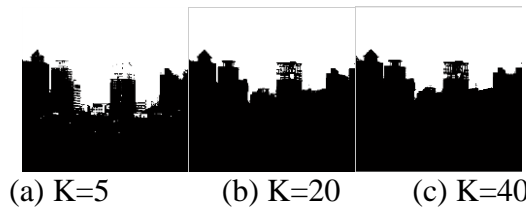
(1) In the fog image, all pixels are randomly assigned to the K cluster, the average value of each cluster is calculated, and the mean of the cluster is used as the center point of the cluster;

(2) Calculate the distance between each pixel and the center of each cluster, and assign the pixel to the smallest cluster;

(3) Repeat the step 2, recalculate the mean of each cluster. When the Eq.2 reaches the best state, stop the iteration.

**2.2 Selection of cluster.** Clustering K value is a direct result of the final image segmentation results. When K is small, it will cause false segmentation; When K is too large, it will increase the computational complexity of the algorithm, and increase the time consumption. The experimental results demonstrate that when the K value reaches a certain value, the segmented sky region is close to the sky range of the original image.

When the clustering of K, respectively, is 5, 20, 40 the result of sky region segmentation is shown in Fig. 1.



**Figure 1** Segmentation results of different K clustering

From Fig.1, when  $K = 5$ , the left side of the building outline was wrongly classified for sky region, the sky area is segmented by mistake; When  $K=20$ , the left side of the building has been separated from the sky area; When  $K=40$ , from Fig. 1 (c) can be seen, the sky area unchanged. When increases the number of K-means clustering, it will increase the complexity of the algorithm.

### 3 Image Defogging Algorithms

In article [9], Zhu proposes a defogging algorithm based on sky regions. The grey value of the sky region of the image is not a constant value, but a constant range. By observing image gray histogram, there is a steep peak in the large region of the gray image histogram, and the peak corresponds to the sky area range of the image. As long as segmenting the peak from the histogram, the rest of the block overlapping histogram equalization processing can get a clear image. Based on this idea, this paper proposes a kind of defogging algorithm based on K-means clustering that firstly using K-means clustering to segment the sky region of the image, making adaptive histogram equalization process on non - sky region, and finally getting a sharp image.

Specify clear image steps are as follows.

- ① Fog image is transmitted to color space, and the luminance component is extracted;
- ② According to the input cluster number, all the image pixels are randomly assigned to the K cluster, and the initial cluster center of each cluster is determined;
- ③ In accordance with the principle of minimum Euclidean distance, all the pixels are re assigned to the nearest neighbour clustering, and calculating the mean value of each new cluster as the center of the cluster;
- ④ Repeat step 2 and 3 until all clustering centers are not changed;
- ⑤ Extract the segmentation results, select the maximum and sub large number of the cluster's location as the sky region of the fog image, and mark the location of the sky region in the original image;
- ⑥ Segment the sky region of the fog image and maintain the brightness of the sky region unchanged, then use the adaptive histogram equalization to process the non-sky region;
- ⑦ Image fusion between the processing results of the sky area and non- sky region is carried out. The color space is transformed, and the final image is enhanced.

### 4 Algorithm Chart Flow

The algorithm is proposed in article [9]. The colour image is segmented into three color channels directly in the sky region, and then the maximum segmentation threshold is selected as the final segmentation threshold in three channels. The algorithm in this paper is that transforming the color

space and extracting luminance component of the image. Use the clustering algorithm to segment the sky region, and maintain the brightness of the sky region unchanged. Use the adaptive histogram equalization to process the non-sky region in the luminance component. The processed sky region and the non-sky area are fused to obtain the luminance component, then the hue and saturation component are maintained, and finally the clear image is getting by transformed the color space. The specific chart flow is shown in Fig.2.

## 5 Experimental Results

In this paper, the experiment using computer Inter(R) Core(TM) i3-2330 CPU@2.2 GHz, memory is 4G, the operating system is Windows 7, experimental platform for MATLAB R2013b. The proposed algorithm will be compared to the results of the literature [9] algorithm. Defogging effects of the two algorithms are as shown in Fig. 3

### 5.1 Subjective evaluation

In Fig.3, there are 4 groups from the top to the bottom. They are the primary group to the fourth group. In the first group, the result of literature [9] is a partial light, the right banner on Tiananmen has disappeared, and some fog appears still in the image. In this paper, the far banner and the near garden flag leaves are able to see clearly, and in consistence with the human visual system. In the second group, the result of literature [9] is dark and the bank's trademark blurred. The result in this paper is not only the mark and window of bank more clearly, but the outline of the car on the road can also see clearly. In the third and fourth group, the results of article [9] were distorted in the sky area. The outline of the motorbikes is missing in the fog in the third group. The result of this paper is that not only the distortion of the sky area disappears, but also the contour of the rider can be seen clearly.

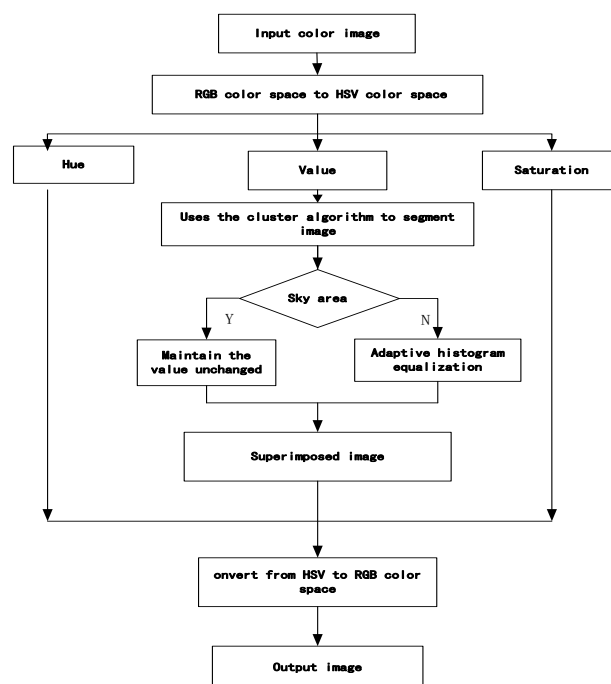


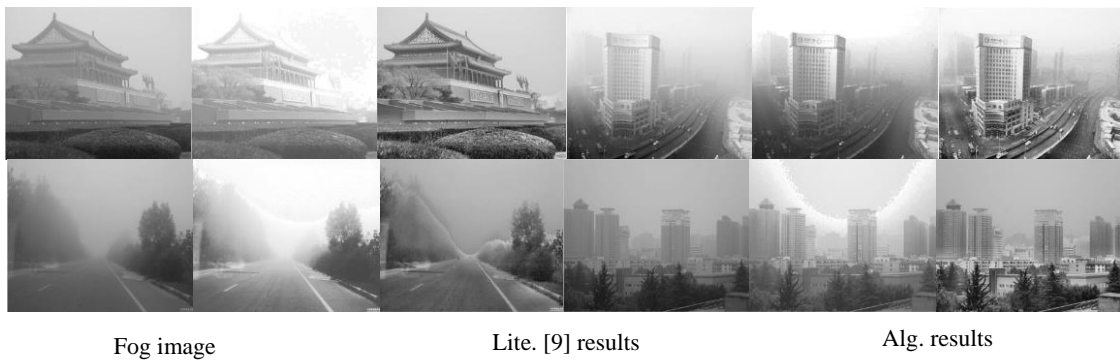
Figure 2. Algorithm chart flow

## 5.2 Objective evolution

Subjective evaluation is closely linked to the culture and profession of the observation. Therefore, in order to reduce the influence of the subjective evaluation, the information entropy  $S$  and the average gradient  $AG$  as objective evaluation parameters are used to evaluate the results of defog. Among them,  $S$  is a measure of the amount of information contained in the image;  $AG$  is used to measure the image sharpness. Greater of  $S$  and  $AG$  image, the better the results of defog.  $S$  and  $AG$  calculation formula is as follows:

$$S = -\sum_{i=1}^{256} p(i) \log p(i) \quad (3)$$

$$AG = \frac{\sum_{x=1}^M \sum_{y=1}^N \sqrt{\frac{F_{(x)}^2 + F_{(y)}^2}{2}}}{(M-1) * (N-1)} \quad (4)$$



**Figure 3.**Experimental results

In Eq.3 and Eq.4,  $p(i)$  represents the frequency of each gray level in gray image;  $M$  and  $N$  is the size of the image;  $F(x)$  and  $F(y)$  are respectively the gradient along the horizontal and vertical direction.

In table 1, it shows two objective evaluation parameters of different algorithm.

**Table 1** Defogging objective evaluation of Figure 3

Image group	Alg. name	S	AG
First	Lit.[9]	6.3755	4.1508
	Pap Alg.	7.2564	8.2210
Second	Lit.[9]	5.3886	3.1811
	Pap Alg.	7.5011	7.1663
Third	Lit.[9]	6.7751	2.8192
	Pap Alg.	7.0019	3.7708
Fourth	Lit.[9]	5.6824	3.6630
	Pap Alg.	6.9925	6.8386

The size of the image is  $450 * 600$ . From the table 1, in the first, second and fourth group,  $AG$  is about two times as high as the literature [9].  $S$  is about one and a half times than the article [9]. In the third groups,  $S$  and  $AG$  of the algorithm are improved, but the range is not large.

## 6 Conclusions

In article [9], the result of defogging still remains a lot of fog in the image and false segmentation. In this paper, an image defog algorithm based on K-mean is proposed. Experimental results show that when the number of clusters is 20. The sky area of the image can effectively segment. The experimental results have a more thorough mist removal and more accurate sky region segmentation, and more in line with the requirements of the human visual in subjective. But the algorithm still needs to be improved. When there is excessive number of clusters, it will increase the time consumption.

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