

# An Improved Haze Removal Algorithm Based on Genetic Fuzzy Clustering

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## Abstract

*Aiming at the degeneration phenomenon of images taken in mist, according to the features of the degraded images, an improved haze removal algorithm based on genetic fuzzy clustering is presented in this paper after analyzing its defects and shortcomings. Firstly, the improved atmospheric scattering model is established. Secondly, the original image is converted into a standard image through the improved model, and then we present a new multi-scale image edge detection by genetic fuzzy clustering. Based on this observation, we can use the multi-scale image edge detection to estimate the haze thickness directly and recover a high quality haze-free image. The new algorithm uses good global search ability of the genetic algorithm, which will implement the transfer from the scene defogging problem into the optimal estimation problem under global contrast optimal point. Compared with other algorithms for degraded images, the improved haze removal algorithm not only detects image edge precisely, but also has better performance in situations of dense haze. Theoretical analysis and experimental results demonstrate that, the new algorithm improved in this paper are effective for removal of fog-degraded images, and can be applied to the practical situations.*

**Keywords:** *Haze Removal Algorithm, Atmospheric Scattering Model, Edge Detection, Depth Region Segmentation*

## 1. Introduction

There are a lot of suspending particles in foggy weather, as a result of these particles, weather degraded images captured in fog have poor contrast and low visibility, this significantly affects the image monitoring and outdoor visual systems [1], so it is great value for the research on defogging of the degraded images. Images of outdoor scenes are usually degraded by the turbid medium in the atmosphere; the degraded images lose the contrast and color fidelity [2]. Degraded images that were captured in foggy weather, on the surface, showed blurred compared with that in sunny weather. Essentially, the degraded image belongs to contrast degradation problem, that is the high gray values part had been weakened and the low gray value part is enhanced, resulting in the distribution of gray values tend to center, which is the cause of the degraded image, we called the process of clear removal [3]. Haze removal is highly desired in both computational photography and computer vision applications [4].

At present, there are two kinds of algorithm for removal of the degraded images [5]. First one is removal algorithm based on unphysical model, it can achieve the purpose of defogging by enhancing the image contrast, and this algorithm can only improve the relative quality of image, but cannot achieve defogging in the sense [6]. Second one is removal algorithm based on physical model; it requires the sense depth and the parameters of physical model [7, 8]. A few researches are concentrating on the analysis of the complex physical model. Due to the complexity of modeling situations, many of these algorithms are restricted in practical applications.

However, haze removal is a challenging project in the image processing, because the efficiency of removal is dependent on the unknown depth information [9]. Although some algorithms have been made in this area, at least two major obstacles must be overcome before a fully automated system should be realized. The depth information and the parameter of the model are established to solve them [10]. Several under-constrained problems are associated with them. Therefore, many algorithms have been proposed by using multiple images or additional information [11], it not only increases the cost, but also brings difficulties to the practical application of removal.

The removal algorithm of the literature [12] has good performance, but it needs two images in the same sense of different weather situations. Polarization algorithm of the literature [13] removes the haze effect through two or more images taken from different degrees of polarization. In the literature [14] more contrast information are obtained from multiple images of the same scene under different weather conditions. The removal algorithms of the literature [15] require the rough depth information either from the user inputs or from known 3D models.

Recently, the study of algorithms based on single image haze removal has made a great progress [16]. The success of these algorithms lies in using a stronger prior or assumption, this algorithm establishes the fog removing model through a prior, and it achieves images of high quality by estimating the fog concentration directly, but this algorithm relies on a powerful prior or assumption, because dark channel prior is a statistical regularity, it might doesn't work well to some special images. For example, dark channel prior is invalid when the scenery is close to the atmosphere and not covered with shadow. Although these algorithms presented methods from different angles to improve the quality of fog-degraded images, these algorithms do not take the inherent fuzzy attribute of the degraded images.

## 2. The Improved Physical Model

Under the fog and other inclement weather conditions, the degraded image is not clear, which is mainly due to atmospheric scattering, and atmospheric scattering is mainly caused by suspended particles in the air. Mie' scattering theory gives the degradation model of atmospheric degraded images [17], which describes the light intensity of scene image in the fog; it can be equivalent to the linear superposition of the radiation and the scattering light.

The foreign particles is a light source in the process of atmosphere scattering, and it will cause ambient light reflection effect, meanwhile, the light in this part is also received by receiving device, so this process is known as optical model of atmospheric environment. In most cases, ambient light model is accompanied by attenuation model, especially in the fog, the two models exist simultaneously, and it is expressed as:

$$E = E_{\alpha} + E_d = E_{\infty}(1 - e^{-\beta d}) + R e^{-\beta d} \quad (1)$$

In the model,  $R$  is the radiation intensity of the scene under sunny weather;  $E_{\infty}$  is the intensity of the sky radiation;  $d$  is called the scene depth;  $\beta$  is called atmospheric scattering coefficient. From atmospheric scattering perspective, Eq. (1) is called atmospheric scattering physical model.

As can be seen from the atmosphere scattering model, in order to realize defogging of the degraded image, it must estimate the atmospheric scattering coefficient and the scene depth. However, it might be a little bit tough to obtain the parameters, meanwhile, in only one case of degraded image; the scene depth value is not the only, and, it will miss depth information during the transformation process, therefore, it has certain difficulty only based on the atmosphere scattering model.

In order to achieve the goal of an image to defogging effectively, it requires improving the degraded image restoration model. An improved atmosphere scattering model of fog

degraded image is put forward, which bases on the statistical analysis of atmosphere scattering model. It becomes apparent that in order to apply this new atmosphere scattering model to removal, we have to pay attention to the problems of the atmospheric scattering coefficient and the scene depth.

By observing a large of degraded images, although the shooting scene in the whole atmospheric scattering coefficients is consistent with the hypothesis, we found that it could not always be expected. But for the target object in the scene at the same depth, it is possible that the assumption is met. Thus, according to the atmospheric scattering model, it only needs to estimate the normalized radiation degree of each pixel in the image. We come to an important conclusion, the model  $E_d$  and  $E_a$  are constants. So we get the following improved image degradation model, namely,

$$E_i = \omega_i E_{i0} + E_\infty (1 - \omega_i) \quad (2)$$

Where  $\omega \in [0, 1]$ , because the model is got under the assumption at scenic spot of the same depth, it can realize the recovery on the single image scene of the same depth. Therefore we also call Eq. (2) as the degradation model of the depth [18]. Because the global scene depth approximate consistent image can be seen as multi-depth images of special circumstances, therefore, the improved united model is put forwarded:

$$E = \bar{\omega} E_0 + E_\infty (1 - \bar{\omega}) \quad (3)$$

In the model,  $\bar{\omega}$  is the vector of weight parameter, dimension of a vector space is relied on fixed number of regions in the same depth image, thus, aiming at the defogging algorithm, it needs to solve the weight vector. The improved atmosphere scattering model is a matter of great significance, through the improvement of the model, it will implement that the complex problem about degraded fog image transferred into simple problem of solving the weight vector composed by several coefficient. The improved atmosphere scattering model can decrease the subjectivity about deciding index weighting and the complexity about calculating optimization model.

### 3. Edge Detection based on Genetic Fuzzy Clustering

Clustering analysis is an important technology in edge detection, and it has been widely used in areas such as statistics, image processing, information retrieval, biology and machine learning. When we use the improved atmosphere scattering model, the primary contents: firstly, the edge detection of degraded image. Edge detection is an essential step in image analysis and recognition. It is an important technology in the image preprocessing procedure. Secondly, image segmentation pretreatment, the purpose of segmentation is to establish weight vector for the improved atmosphere scattering model.

Image edge detection is a very important and hot research field in image processing, it has many algorithms at present, which is the basis of further image processing and analyzing. So far, there are many traditional arithmetics, such as canny algorithm, Sobel algorithm and Roberts algorithm and so on [18]. However, these algorithms are always more sensitive to noise and don't have the thought of automatic room. In fact, images have different features in different scale. Considering these reasons, it is obvious that we need to find an edge detection algorithm which can adaptively affect the marginality of different images and also has good ability of noise restraining.

Classical edge detection always has different localization [19]. The task of finding the edges is to find true physical boundaries, which is a hotspot in image processing. Genetic Algorithm (GA) is a kind of random search algorithm which uses natural selection and natural inheritance mechanism for reference. It was put forward in 1975 [20]. GA is a kind of entirely optimizing search algorithm, it is provided with many characteristics, such as simpleness, currency, robustness, and fit for parallel processing [21]. People did a

lot of researches on how to use genetic algorithm to the image edge detection, but most of them are based on classical edge detection.

In order to realize the effective partition of image edge points, we need a perfect clustering algorithm. As the most popular kind of fuzzy clustering algorithm, FCM algorithm is widely used in every field. It is a local search algorithm that finds the optimal solution to the research questions through the iterative mountain climbing algorithms. So it is very sensitive to the initialization and easy to fall into the local minimum. Aiming at solving these problems, people have put forward various improvement methods [22]. As a global optimization method, Genetic algorithm operates the population made of multiple individuals. And using genetic operator to exchange the information between individuals, so that individuals in groups can evolve from generation to generation, thus gradually approaching optimal solutions. Its main advantages are simple, universal, robust and suitable for parallel processing. So it is a kind of effective method to solve complex problems, and it can overcome the problem that FCM is sensitive to initialization.

In order to effectively detect the edge points, the features of the edge must be given reasonable description and measurement. In image processing field, gradient information is usually used to characterize the extent of mutation about the pixel, and this is also the most basic feature of edge points. Considering when an image is analyzed in wavelet in multiple scales, each scale provides certain edge information, wavelet transform have the feature of zoom at different scales, and the maxima value in multiple scales can well characterize the singularities of catastrophe points.

By the above analysis, we can conclude that the maxima value of modulus in wavelet transform have distinct transmission characteristics, and this indicates that the wavelet transformation in each of the dimension has strong correlation, and stronger correlation at the edges, while the wavelet transformation doesn't have obvious correlation among scales. Basing on this characteristic, it is feasible to multiply the wavelet coefficients of adjacent scales to enhance signal directly and reduce the noise.

Supposing a two-dimensional image is  $f(x, y)$ , and two-dimensional corresponding scale function is  $r(x, y)$ , then the corresponding two-dimensional wavelet function is:

$$\psi^1(x, y) = \partial[\gamma(x, y)] / \partial y \quad (4)$$

$$\psi^2(x, y) = \partial[\gamma(x, y)] / \partial y \quad (5)$$

Wavelet transform of two directions A and B is put forward:

$$W_2^1 f(x, y) = f(x, y) * \psi_2^1(x, y) \quad (6)$$

$$W_2^2 f(x, y) = f(x, y) * \psi_2^2(x, y) \quad (7)$$

Wavelet transform provides a better method for studying the multi-scale transient representation of images processing.

According to the feature that wavelet transformation modulus maxims of the signal and the noise, which have distinct characteristics of propagation in different scales, it is available to make wavelet coefficients of adjacent scales multiply to enhance the signal and reduce the noise.

Definition: if  $Cor_i(x, y) = W_2^i f(x, y)$ .  $W_2^{i+1} f(x, y)$  is the correlation coefficient in the point  $(x, y)$  of adjacent scales  $i$  and  $i+1$ , and supposing  $i=1, i=2, i=3$ , then  $Cor_1(x, y), Cor_2(x, y), Cor_3(x, y)$  form the eigenvector  $\{Cor_1(x, y), Cor_2(x, y), Cor_3(x, y)\}$  of the edge point.

The edge detection algorithm based on wavelet transform and genetic fuzzy clustering premises the image reduction with profiles defined.

#### 4. Depth Region Segmentation

Clustering analysis is an important technology in region segmentation. The problem of image segmentation is coincident with the problem of clustering. Image segmentation plays a fundamental role in image processing as a requisite step in such tasks as object detection and tracking. The processing of image segmentation often takes more time and lacks of precision or it is unrealistic. Therefore, how to realize the real-time automatic quick image segmentation is still extremely important and the problems are yet to be solved effectively.

When we use improved unified atmosphere scatters physical model, the removal process contains edge detection and image segmentation. The purpose of segmentation is to establish weight vector for the improved atmosphere scattering model. A new depth region segmentation algorithm is presented in this paper, which consists of two steps: segmentation and luminance adjustment.

Image segmentation is a key technology in image processing, it refers to the data to be analyzed, which is a regional breakdown of the data fragments extracted from the image of interest, and then do further processing, (Image segmentation is to divide the image into several unique properties of a particular area and interested target technology and process are put forward) and other data will be discarded. The main object of the region segmentation is to reduce the amount of data for subsequent processing.

At present, image segmentation is applied in many fields, more researchers have been devoted to removal algorithm based on image segmentation, which can be divided into three categories depend on the processing method: the edge-based, the region- based and the texture-based. Now we adopt the image segmentation algorithm based on edge detection. So to achieve scene depth, firstly, we point edge points to the closed border, secondly, create mark matrix, so according to each target, we can boundary mark matrix in depth, and thus we can get quality regional segmentation, it also can realize the scene depth.

According to the detection of edge points, we should do deep regional segmentation to the degraded image. Because the conversation might cause the shift of the scene depth between the goals and objectives or the target and the background in the image, consequently, through the image segmentation, it can complete the dept region segmentation by the division of a number of the same depth.

Assuming the pixel of each goal in degraded image is always in the same depth, the background area is also considered to be the goal, so the degraded image is divided into a number of goals, it can be divided into a number of different depths areas, so that the degraded image can realize depth region segmentation.

After the edge detection of the degraded image, it is necessary to connect the edge points to form a target boundary. When multiple small closed boundaries appear in the connection process, in order to avoid the phenomenon of too many divided regions, we can merge some small closed regions which have similar regional characteristics. That is what we should pay attention to.

Through depth region segmentation, we determined a number of depth areas, in order to further define the vector in each weighting parameters, the value is proposed based on contrast global optimal parameters in the improved atmosphere scattering model, which can proof that genetic algorithm is efficient, fast and robust advantages, the optimal parameters problem can be solved by adapted way. Due to the weight parameters is [0, 1], so we adopt floating-point coding method.

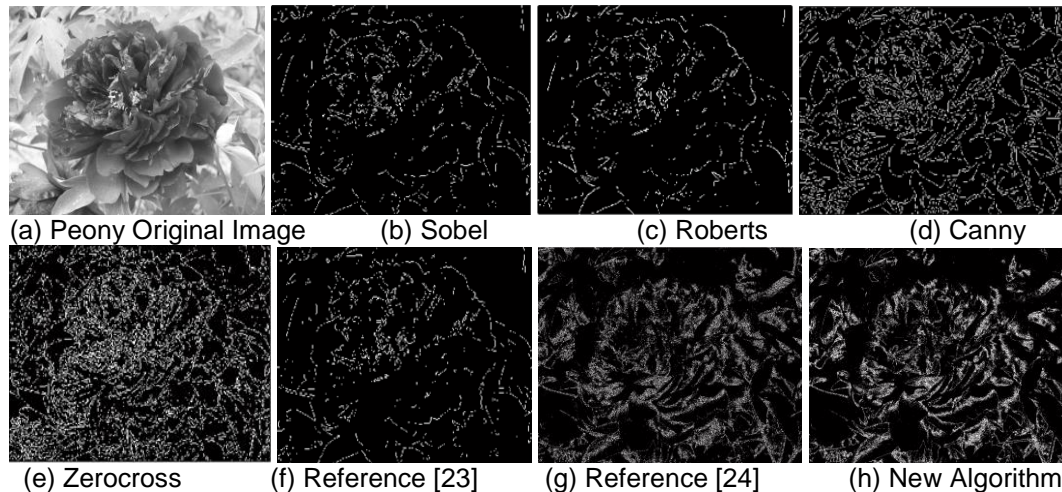
In fact, contrast is bigger namely gradient value, which can be seen clearly in the fog day. Therefore, in the removal algorithm, *Sobel* image should be effect the modes and image quality evaluation function, it represents the image contrast in the global sense, so the metrics to determine fitness function below

$$fitness = \sum_{(x,y) \in I} |Mf(x,y)| \quad (8)$$

Here,  $Mf(x, y)$  means Sobel Gradient mode of images at any point  $(x, y)$ , the bigger of fitness, the higher image contrast, and the better quality of the images.

## 5. Experimental Results and Performance Analysis

In order to verify the effectiveness of the edge detection algorithm, the paper combines classic operator (Sobel, Roberts, Canny and Zero cross operator) and genetic fuzzy clustering algorithm proposed in reference [23], a proposed fuzzy enhanced multi-scale edge detection algorithm in reference[24].The comparison results of different edge detection algorithms are shown in Figure 1.



**Figure 1. The Comparison Results of Different Edge Detection Algorithms**

In the course of the experiments, the parameter selection of the new algorithm is critical, by analyzing the comparison results, the criteria for parameters selection are determined. Using fuzzy clustering analysis, it can realize the adaptive search of edge point. With the proper parameters the simple model can acquire a good result. Where the locate populations is 40, iterations generations are 100, mutation probability is 1%, crossover probability is 50%, and the number of categories are two.

Figure 1 shows the comparison results of different edge detection algorithms, Figure 1 (a) is the peony image. Edge detection result by Sobel operator is shown in Figure 1 (b), the edge detection is not continuous, poor noise immunity (Noise immunity is poor).The result of edge detection by Roberts operator is shown in Figure 1(c), edge thick and relatively smooth, but lost a lot of detail edge, such as petals. It is company together between edges and noise by Canny, which is shown in Figure1 (d). there is a phenomenon of false edges by Zerocross operator which is shown in Figure 1 (e).Edge detection is relatively results by reference [23] and reference [24], which are shown in Figure 1 (f) and Figure 1 (g). It can extract most of the edges, but vaguer peony petal edges, details are not clear, which can not reach a better edge detection results to weak edges. The results of edge detection are shown in Figure 1 (h) by new multi-scale image edge detection based on genetic fuzzy clustering. The new edge detection algorithm is not only the overall clear and natural, but also the edge has been peony spend more reserved. Also retained at the periphery of the contour information more effectively suppress noise , by comparing the experimental results of Figure, it can be seen in this paper ,a new algorithm for better positioning accuracy of the extracted edge line more detailed, which shows the effectiveness of the new algorithm.

In order to verify the new algorithm, the effect of noise pollution can be extracted after receiving the edge detail of the image. By the calculation of Signal-to-noise ration (SNR), we can measure the ability anti noise. the smaller of SNR, obviously, the smaller filter out

noise, the worse ability of noise suppression, conversely, the bigger of SNR, the greater ability of noise suppression.

The SNR of edge image under different noises are shown in Table 1. As can be seen from Table 1, the lower SNR when we used edge detection algorithm, such as Sobel edge detection, while higher SNR of the new algorithm, obviously the new edge detection algorithm can effectively suppress noise.

**Table 1. The SNR of Edge Image Under Different Noises**

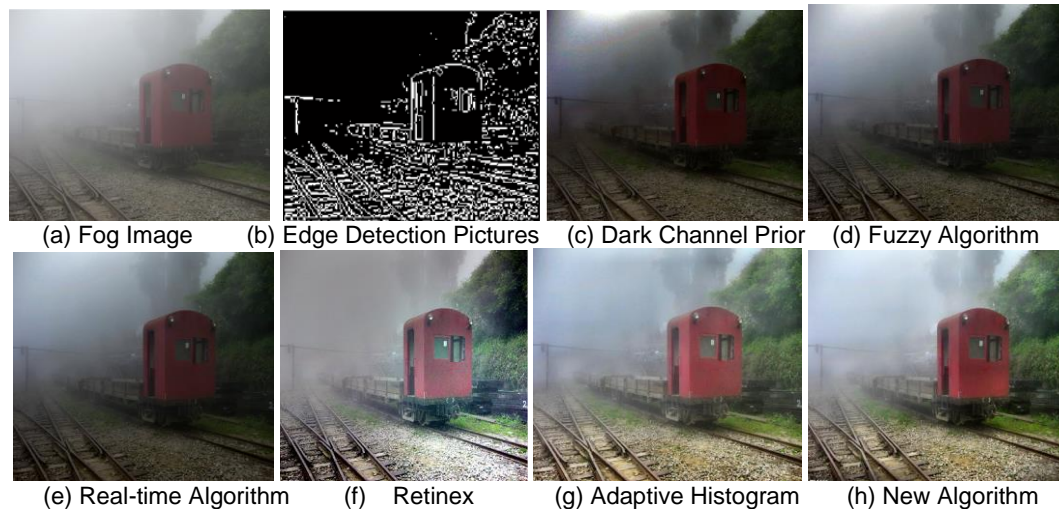
Noise	Sobel algorithm	Canny	New algorithm
0.02	13.78	19.25	28.36
0.04	12.65	18.76	27.75
0.10	10.98	17.95	26.32

Future verification for the new algorithm in the real time aspect is conducted through experiments, in the experiments; two algorithms (Sobel algorithm, Gauss-Laplace algorithm) compared with the new edge detection algorithm. The results of processing time under different algorithms are shown in Table 2, through the observation of treatment time in Table 2, we can measure the performance of the algorithm. We can see that the new edge detection algorithm with faster and better real-time than Sobel algorithm and Gauss-Laplace algorithm, it also can be further applied to real-time image processing.

**Table 2. The Results of Processing Time under Different Algorithms**

Image Size	640×480	800×600	1024×768	1280×1024
Sobel algorithm	3.3521	4.6854	8.2654	12.258
Gauss-Laplace algorithm	1.6582	3.1247	5.9821	9.1652
Proposed algorithm	0.5208	0.8361	1.2362	2.1526

In order to validate the effectiveness and the stability of improved haze removal algorithm based on genetic fuzzy clustering. Edge detection is an essential step in image analysis and recognition. Secondly, Image segmentation pretreatment, the purpose of segmentation is to establish weight vector for the improved atmosphere scattering model, which will make the further color and luminosity tweaking easier, in the end, luminance adjustment, the relative modules are designed based on leading algorithm of contrast, luminance adjustment and sharpness adjustment. Compared with other algorithms for removal, we take a large number of experiments based on MATLAB experimental platform. The experimental results are shown in Figure 2.



**Figure 2. The Comparison Results of Different Removal Algorithms**

To further validate the superiority of the improved haze removal algorithm, in experimental study. Figure 2(b) is edge detection of degraded image, the processing results are shown in Figure 2(c) based on the dark channel prior algorithm, the comparison removal results of fuzzy algorithm and real-time algorithm are shown in Figure 2 (d) and Figure 2 (e), and Figure 2 (f) is removal result based on Retinex, Visibility, after histogram equalization. The processed image Figure 2 (g) nearby gray level lower, contrast drops, obviously, it is not the effect of what we expected. Figure 2 (f) is Retinex algorithm with single scaling the treatment effect of uneven illumination algorithm in dealing with the problem, but often with good image contrast when handling with no obvious advantages, the processed though the obvious enhancement border, but not eliminate the feeling of "the mist". After improving physical model of optimal image to fog the new algorithm processed image Figure 2 (h) the near and distant got different enhancement, the scenery trenchant, especially distant trees of details the outline of a clear, the effect of fog drop is good and the colour of nature.

## 6. Conclusions

In order to remove the reliance on the scene depth information, this paper proposed an improved haze removal algorithm based on genetic fuzzy clustering, according to the analysis of the mechanism of imaging in fog, this paper conducts a full investigation into the enhancement of fog-degraded images.

Firstly, the atmospheric scattering model is established. Based on the hue preservation principle, images are transformed both in the RGB and CMY color spaces; the enhancement methods in gray scale are generalized to the color space, the original image is converted into a standard image through the improved atmospheric scattering model.

Secondly, aiming at the characteristic of scene depth variations on fog images, new multi-scale image edge detection is used to enhance the local information of images. Algorithms including Sobel, Roberts, Canny, and Zerocross are deeply analyzed in detail, and their applications on fog images.

Thirdly, depth region segmentation and luminance adjustment are discussed. Retinex, Dark Channel, Fuzzy algorithm, and adaptive histogram equalization are introduced in experimental study.

The experimental results show the improved algorithm based on genetic fuzzy clustering is able to removal the fog effectively, which is superior to some existing algorithms. It also has many advantages such as low computation, fast processing speed



and no manual intervention. This research will be a solid base for the further investigations on removal of fog-degraded images.

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