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Genetic algorithm-based parameter selection approach to single image defogging

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ABSTRACT

Image defogging is widely used in many outdoor working systems. However, owing to the lack of enough information to solve the equation of image degradation model, existing restoration methods generally introduce some parameters and set these values fixed. Inappropriate parameter setting will lead to difficulty in obtaining the best defogging results for different input foggy images. This letter proposes a novel defogging parameter value selection algorithm based on genetic algorithm (GA). We mainly focus on the way to select optimal parameter values for image defogging. The proposed method is applied to two representative defogging algorithms by selecting the two main parameters and optimizing them using the genetic algorithm. An assessment index of image defogging effect is used in the proposed method as the fitness function of the genetic algorithm. Thus, these parameters may be adaptively and automatically adjusted for the defogging algorithms. A comparative study and qualitative evaluation demonstrate that the better quality results are obtained by using the proposed method.

1. Introduction

Most automatic systems assume that the input images have clear visibility, therefore removing the effects of bad weather from these images is an inevitable task. In the past decades, extensive research efforts have been conducted to remove fog or haze from a single input image. Most of these methods [1–4] intend to recover scene radiance using the image degradation model that describe the formation of a foggy image. Tan [1] removed fog by maximizing the local contrast of the restored image. Nishino et al. [2] proposed a Bayesian probabilistic method that estimates the scene albedo and depth from a foggy image with energy minimization of a factorial Markov random field. He et al. [3] estimated the transmission map and the airlight of the degradation model using the dark channel prior. Tarel et al. [4] introduced an atmospheric veil to restore image visibility based on the fast median filter. However, these methods are controlled by a few parameters with fixed values that cannot be automatically adjusted for different foggy images.

In recent years, people are quite interested in automatic fog removal, which is useful in applications such as surveillance video [5], intelligent vehicles [6], and outdoor object recognition [7]. In this letter, we thus focus on the genetic algorithm-based adaptive parameter adjustment for single image defogging.

The motivation of using genetic algorithm for image defogging is that the parameter selection and function maximization can be closely related problems, since acquired the best parameter values also simultaneously solved the function maximization problem, and constructing a good object function actually ensures the best parameter values for image defogging effect. The essence of genetic algorithm is its global optimization performance, that is, the

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(a) (b) (c) (d)

Fig. 1. Fog removal results with fixed parameter value. (a) Original image. (b) Unpleasing contour effect with $\omega = 0.95$. (c) No obvious visibility improvement with $\omega = 0.65$. (d) Smoother sky region using $\omega = 0.12$.

fitness function may reach its maximum with the optimal parameter values, and using genetic algorithm the probability of finding out the global optimization solution is the highest in most intelligent search algorithms. It is widely used to generate useful solutions to optimization problems and it can be also used for digital image processing, such as image segmentation [8], image enhancement [9], etc. Therefore, the parameter value selection of image defogging is simulated as an optimization problem, and the genetic algorithm is used to optimize the sensitive parameters in the proposed method. Experimental results demonstrate that the better quality defogging results can be obtained by using the genetic algorithm.

However, due to the lack of proper objective criterion of defogging effect as the fitness function, present defogging algorithms seldom use genetic algorithm to effectively remove fog from a single image. Though the objective image quality evaluation methods have achieved some promising results, they are just applied to assess the quality of degraded image, such as image denoising results and image deblurring results. The aim of defogging algorithm is to recover color and details of the scene from input foggy image. Unlike image quality assessment, the fog can not be addressed like a classic image noise or degradation which may be added and then removed. Meanwhile, there is no easy way to have a reference no-fog image, and the quality evaluation criteria of degraded image, such as the structural similarity (SSIM) [10], the peak signal-to-noise ratio (PSNR) [11], and the mean square error (MSE), are not suitable for assessing image defogging effects. This makes the problem of adaptive parameter adjustment of defogging algorithm not straightforward to solve.

In this letter, we mainly focus on the way to select parameter values for single image defogging. Here, the defogging effect assessment index presented in our previous work [12] is taken as the fitness function of the proposed GA-based method to adaptively adjust the parameter values for different input foggy images. In Section 2 of the letter, the limitation of existing methods are described. Section 3 introduces the proposed parameter value selection approach to single image defogging. Experimental results and conclusions are presented in Sections 4 and 5, respectively.

2. Limitation of the existing defogging methods

Most current defogging methods recover the scene radiance by solving the image degradation model. Since the model contains three unknown parameters and the solving process is an ill-posed inverse problem, it is thus inevitable to introduce many application-based parameters that used in various assumptions for image defogging. A large quantity of experimental results shows that the selection of the algorithm parameters has direct influence on the final defogging effect. However, there exists a major problem for the parameter setting in most defogging algorithms, i.e. the parameters may all have fixed values in the defogging algorithms. Therefore, the proposed approach first split the set of algorithm parameters into two sets: sensitive parameters set and less sensitive parameters set. Then a criterion is used to select the best sensitive parameters using a genetic algorithm. The reason why the parameter selection is needed for the proposed method is that optimizing too many parameters will cost too much computing time. Therefore, we choose two main sensitive parameters which have significant effect on the final defogging results to optimize, and other less sensitive parameters are set with fixed values. However, if time permits, all the algorithm parameters can be optimized using the proposed approach.

In our experiments, we find that the fixed parameter values caused that the fog removal algorithms just have good defogging effect for a certain kind of foggy image, and the algorithms may not work well for the images captured under other foggy conditions. For example, He's algorithm [3] has mainly three parameters to control: ω which alters the amount of haze kept at all depths, c the patch size for estimating transmission map, and t_0 restrict the transmission to a lower bound to make a small amount of fog preserve in very dense fog regions. All these parameters have fixed value suggested by the authors, such as the fog parameter ω, which is set to be 0.95 in the algorithm [3]. Our experimental results given in Fig. 1 using He's algorithm [3] show that, if ω is adjusted downward, more fog will be kept, and vice versa. Using $\omega = 0.95$ keeps a slight amount of fog effect around at all depths. However, the experiments show that ω sometimes needs to be decreased when an image contains substantial sky regions, otherwise the sky region may wind up having artifacts. An example showing the need to decrease ω is presented in Fig. 1. The defogging result with $\omega = 0.95$ is shown in Fig. 1(b). One can clearly see that the sky looks contoured since the fog removed by He's algorithm was too strong in this region, and the defogging result has no obvious visibility improvement with $\omega = 0.65$. If setting $\omega = 0.12$, the sky region becomes brighter and smoother, which makes the whole image look more natural.

Most defogging algorithms have introduced some parameters, which lead to user interaction and make the fi-