Single Image Dehaze Processing and Evaluation Based on Dark Channel Prior and Deep Learning

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CONTENTS

Abstract

The purpose of image dehazing is aimed at trying to recover the true information from a foggy blurred image. The work of this thesis is based on image enhancement and deep learning techniques, and the training was carried for image dehazing correlations, with very ideal evaluation effects. In real life, because of the imperfection of equipment and system, as well as the influence of objective climate, the image is often polluted by noise and becomes blurred and foggy. Because of the real-time processing requirements of remote sensing, surveillance, automatic driving and other electronic equipment, the image dehazing has put forward higher requirements. This thesis provided solutions for two problems: firstly, for the excellent DCP algorithm, the DbGAN algorithm is proposed and implemented in dealing with the hazy image of the highlighted area in the blurred image. Finally, the test result is proved to be feasible. Secondly, according to the single image dehaze characteristics of the hazy image, on the premise of haze-less image, the demand of directly restoring the hazy image is put forward, and the DhNet algorithm is proposed in this work, from the simulation to test results, the algorithm was proved to be advanced.

In order to solve these problems effectively, first of all, let the hazy image becomes clean, and the image details was seen obviously. In this work, neural network was used to learn the image than statistical characteristics well and image dehazing was realized. Based on the convolutional neural network (CNN) algorithm, this work focuses on the influence of activation function on network optimization. In deep learning network, multi features extraction technology was used to learn more abundant features of input image, and how to make better use of adaptive algorithm to optimize the back propagation of the convolutional neural network [1]. Because the back propagation is prone to gradient disappearance, and Unable to complete network training. In order to speed up the training speed of the model and improve the convergence of the algorithm, the dilated convolution techniques are added specially. Combined with the residual learning technology, the deep residual learning image dehazing model based on the convolution network is designed with better noise reduction performance.

One of the proposals of this work is to specially deal with the problem of the high brightness area defect in the dehazing processing of dark channel prior (DCP). It puts forward the DbGAN network learning algorithm, designs the generator and the discriminator. After the restoration of DCP, the RGB value of the image processing bug with the high brightness area is taken as the input content, it is compared with the RGB information of the haze-less image to generate the anti-training. At the same time, it adopts the method of discriminating and set the target image. Finally, RGB processing image is generated. After restoration, the effect of dehazing in the highlighted area is well realized, which makes up for the shortcomings of DCP algorithm. The second proposal of this work was aimed at DhNet to dehaze end-to-end process. Based on the deep convolutional neural network, the hazy image is learned directly from the training data. Because it does not have the sense of reality corresponding to the real hazy image, the hazy image is synthesized for training. Compared with other common strategies to increase the depth or breadth of the network, by changing the cellular convolution method and the dilated conversion method, the image processing field of vision is increased, CNN with moderate size is used to improve noise reduction [2]. Specifically, training DhNet at the level of detail. Although DhNet is trained on synthetic data, the learning network can transform real world images effectively, then improve CNN framework through image enhancement, then improve visual effect. Thought compared with the most advanced single image denoising method, this method improves the removal rate of noise in hazy image, and greatly accelerates the calculation speed after network training, compared with other existing excellent dehazing algorithms finally. From the comparison results, in this work, it can be seen that the improved dehaze algorithm can improve the detail recovery of the dehaze image without losing the definition. In different noise standard deviation than other excellent demisting algorithm in PSNR and SSIM advantages. It is proved that the improved models are advanced significance.

Index Terms: Image dehazing, Dark channel prior, Generative adversarial network, Convolutional neural network, Deep learning.

1. Introduction

1.1. Research Status and Dynamic Analysis

The technology of hazy image dehazing belongs to the field of artificial intelligence. For example, weather environment is taken as the research object when driving automatically, the clarification of hazy image and the consistency evaluation of image quality are the main research directions of computer vision. Starting from physical optics and information science, some achievements have been made in the application of hazy image feature information processing mechanism and prior statistical data processing method, and a solid foundation has been provided for the denoising information processing of hazy image. At the same time, researchers in the field of information science study image information processing from the perspective of mathematics and prior, which is still insufficient to draw lessons from the achievements of image information science. The robustness of the algorithm and the visual perception of the processing effect are not strong. Firstly, the transmittance consistency of the same plane object is maintained, and the filtering operation is not strong enough. The texture fluctuation in the plane of the midcourse transmittance map. This not only makes the transmittance no longer conform to the changing rule of depth information, but also weakens the contrast of haze-less image. Secondly, filtering always regards the neighboring pixel values as reference and recalculates the central pixel values in a certain way, which directly affects the reliable transmittance estimation in the adjacent region of unreliable transmittance and deviates from the original [3]. Reliable value estimation. In order to accurately correct the transmittance, it is necessary to achieve a reliable transmittance estimation with adaptive variations.

1.1.1. Significance

Image is the basis of vision and the main way for human to acquire and utilize visual information. Image is also the entity that directly or indirectly acts on human eyes and produces visual perception [4][5]. The quality of the image will have a far-reaching impact on its subsequent image interpretation, analysis, recognition and accuracy of measurement results.

Due to various factors that lead to the image quality of visual system in real life, the image acquired by imaging equipment has a certain degree of degradation. It is worth noting that in recent years, haze weather frequently occurs throughout the country, which has seriously affected the normal operation of social activities and industrial production. PM2.5 has resulted in a wide range of security problems of monitoring video locking and tracking criminals, computer vision outdoor monitoring, remote sensing systems, flight navigation systems and so on [6]. It poses great challenges, especially for the autopilot technology which has been paid much attention recently. The haze climate will bring great potential safety hazards to its application. Image blurring results in the attenuation of scene features to varying degrees, and the robustness and reliability of related electronic equipment systems working in this environment are greatly reduced. Therefore, the research of high-quality dehazing algorithm for hazy degraded images and the improvement of scientific evaluation system are still the focus of recent research on image processing and computer vision recognition.

Image dehazing technology mainly refers to the removal of haze information interference in the image through certain means, and the restoration of image color, contrast, scene details information, so as to obtain high-quality images, in order to obtain satisfactory visual effects, while obtaining more effective image information, and give theoretical scientific evaluation. It has great engineering application value for reducing the restriction of outdoor imaging equipment such as transportation, video surveillance and navigation system by bad weather conditions and improving the reliability and stability of related systems.

1.1.2. Atmospheric scattering model

Hazy images are photos taken in haze and haze weather, because of the influence of atmospheric water droplets, smoke, fog, dust particles and other turbid media on the absorption and scattering of atmospheric light, resulting in the attenuation of transmission light intensity, which makes the intensity of light received by optical sensors emit. Changes have taken place, resulting in reduced image contrast, narrowed dynamic range, blurred image, lack of detail information, cover-up of scene features, color fidelity decline, unable to achieve satisfactory visual effect. It directly affects the effective play of outdoor surveillance camera system, satellite remote sensing monitoring, intelligent navigation and tracking, military reconnaissance and other systems. It causes a lot of hidden dangers to public safety, road traffic, emergency rescue, national defense security and other operating systems, and directly endangers the national security and the vital interests of the national normal life.

Firstly, image dehazing technology is a very meaningful topic in the field of computer vision system and research. It is a new research direction and has broad application prospects. The related research results can be widely used in daily image processing, video surveillance, aerial photography, safety assistant driving, automobile automatic driving, underwater image analysis, real-time tracking of industrial automatic welding seam and many other fields. Although the research in this field has been vigorously developed at home and abroad, due to the complexity of hazy image and the changeable shooting environment, the existing algorithms and research results of hazy image sharpening need to be improved urgently, and there are still many difficult problems, which have not been effectively solved [7].

Secondly, the objective and scientific evaluation system of haze removal effect is an important basis to measure the effect of haze removal. At present, there are few excellent research results in this field. The evaluation method with better applicability and reliability is an important guarantee for further research on dehazing image processing. In addition to the existing mature image quality evaluation methods, the evaluation algorithm for the effect clarity of dehazing image processing, which is not reliable enough, needs to be further studied. Research.

Therefore, in the broad direction, we aim at the two core issues of digital image haze removal processing, namely image haze removal processing, image processing effect evaluation system, and explores new theory and new means of image haze removal processing technology. In order to improve the performance of vision system widely used in life, industry and other fields in harsh and changeable natural conditions, lay a theoretical foundation. At the same time, it provides a new algorithm for establishing a scientific, reasonable and effective image quality evaluation mechanism of dehazing processing. The principle of hazy image formation is shown in figure 1-1, and the images before and after haze removal are shown in Figure. 1-2.

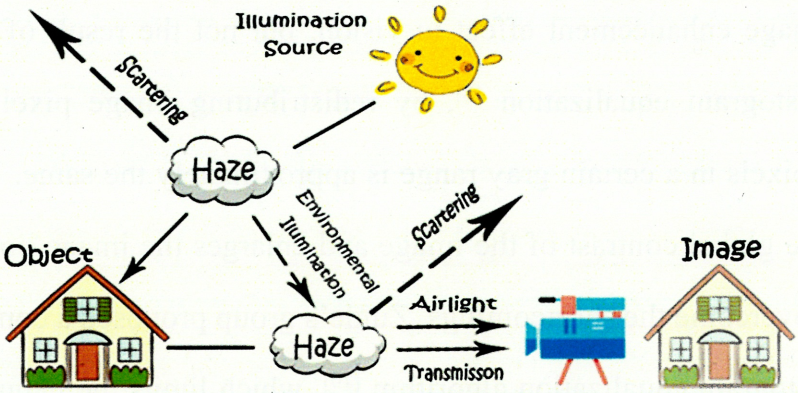

Figure. 1-1 Atmospheric scattering model

[Illumination environmental scattering airlight]

(a) Hazy image (b) Dehaze image

Figure. 1-2. Comparison between for hazy image and dehaze image

1.1.3. Hazy image enhancement based on image processing

Considering the particularity of hazy image, image processing is based on prominent details, contrast enhancement and brightness enhancement, which has a certain image enhancement effect in vision, but not the result of dehazing in essence. Histogram equalization [8], by redistributing image pixel values, the number of pixels in a certain gray range is approximately the same. This method enhances the global contrast of the image and enlarges the image noise easily [9]. In order to overcome the shortcomings, Zuide's group proposed a contrast-limited adaptive histogram equalization algorithm [10], which limits the magnification by clipping the histogram with a predefined threshold before calculating the cumulative distribution function, but it is easy to make the color image color skewed. In terms of image restoration methods based on physical models, some researchers use the atmospheric scattering model [11] proposed by Mcca's model hazy scenes to solve the problem of hazy degraded images. For example, Tan's group and other scholars have found that haze-less image have higher contrast than hazy images [12], which maximizes the local contrast of images, but the restored color is often over-saturated. Specifically, atmospheric scattering model is based on two prior knowledge: One is the haze-less image that have higher contrast than images under severe weather conditions, the other is light that's often smooth between the scene and the observer, and then local pairing of scene images is improved by using Markov random fields (MRF) model. Restore the haze-less image of the scene. The result of this processing method makes the contrast of the image greatly improved, but there is a large halo phenomenon, and the scene appears a certain degree of color deviation, which leads to the unreal image.

In order to solve the problem of excessive distortion of dehaze image, in 2009, K.He's team of the Chinese University of Hong Kong proposed a single image dehazing technology-dark channel prior algorithm [7], and won the CVPR Best Paper Award of the Year, which made the image dehazing technology a landmark breakthrough. Based on the statistical characteristics of outdoor daytime haze-less image the brightness value of pictures in at least one of the color channels of R, G and B is close to zero, a dark channel prior theory is proposed. Combining this prior knowledge with atmospheric scattering model, the transmittance is obtained by dark channel prior, and then corrected by soft Matting algorithm to estimate atmospheric light value. Finally, a better restoration of hazy image is achieved. The dark channel prior method has made a new leap in the field of image dehazing, and many subsequent research methods are mostly based on this method.

However, when the object in the scene image does not satisfy the prior knowledge, the method based on dark channel prior can't achieve good dehazing effect[13][14]. The shortcomings and shortcomings are as follows: Firstly, the computational cost is high, and secondly, the estimation of atmospheric light intensity is inaccurate, which easily leads to color distortion. In view of the above two points, K.He's group made improvements on the basis of dark channel. On the basis of scattering model, Tarel's term used median filter to remove haze quickly [15]. The algorithm assumes that the scene is smooth in the image, except for the edge area of the scene. He and others use the method of improve the execution efficiency of the original algorithm, but this method directly chooses the original hazy image as the guide image, which can't be well restored in the haze-dense situation. The structure information of the original image is obtained, and the color distortion of the restored image in the bright area is caused by the invalidity of the dark channel prior itself in the bright area.

The above method can achieve acceptable enhancement effect for haze degraded images without obvious noise interference. If the hazy image has strong noise interference, the enhancement effect is unsatisfactory. Some methods enlarge the noise sharply while enhancing the scene, resulting in more serious visual degradation effect. Some researchers have proposed some noise suppression methods, using image noise level evaluation and iterative method to synchronize denoising and hazing [16]. Meng's group used context regularization to attenuate noise and enhance image structure [17]. Ge and others used bilateral filtering with changing filter radius to blur hazy image, recalculated the imaging model of hazy days for future generations of transmission rate images, and proposed a method to suppress noise in haze removal process [18].

In image decomposition, Kang and Zhu proposed a texture removal method for hazy image based on Morphological Component Analysis (MCA) [19][20]. The method can be achieved by using bilateral filtering to divide the image into high and low frequency parts and then using sparse coding to learn dictionary. In addition to the haze gray layer in the image and the role of its details. Huang et al. classified dictionary atoms by using support vector machine (SVM) and principal component analysis (PCA) based on Kang, which made the classification of haze depth background atoms more accurate [21].

In recent years, Phased research results are based on the algorithm represented by the perception of haze concentration characteristics, which breaks through and improves the use of previous atmospheric scattering models [22]. Through a large number of Daytime outdoor fog and hazy image samples, statistical characteristics of haze concentration and haze recognition are calculated, including local standard deviation, local average value, and so on. A series of statistical features, such as color saturation and image entropy, are combined with the weighted calculation of each part of the feature, and then the original image is restored by the multi-scale thinning process. This is a kind of learning feature base method. This method can get the image after haze removal very well. In terms of image clarity, contrast and detail recovery, the results of haze removal algorithm based on various physical models are more in line with the subjective requirements of human eyes.

Aiming at color distortion, fine-grained operation based on filtering can easily cause texture fluctuation of transmittance of the same plane, which is not suitable for transmittance optimization. Zhao's group proposed a transmittance estimation strategy based on block offset, which can effectively reduce halo generation, but for residual halo to be processed in the form of substitution, visual defects are prone to appear at the junction [23]. Literature [24][25] improves the sky parts that do not conform to the dark channel prior, but they are all separately processed for the sky obtained from image segmentation, which depends heavily on the segmentation effect.

$$\nabla I(x) = t(x) \nabla J(x) \tag{1-1}$$

1.1.4. Restoration of hazy image based on physical model

The image dehazing algorithm based on physical model is to model and analyze atmospheric scattering from the point of view of physical origin, starting with the principle of haze degradation and the mechanism of blurring.

$$I(x) = J(x)t(x) + A(1 - t(x)) \tag{1-2}$$

Haze restoration of physical model, establishment of physical degradation model during degrading process, inversion of degradation process, it can obtain haze-less image, achieve clear effect of hazy image, and the loss of image information is relatively small, so it has gradually become a research hotspot in the field of image dehazing. This kind of dehazing algorithm has strong pertinence to image processing and presents natural dehazing effect on the premise of retaining the original image information as much as possible [26]. In computer vision, atmospheric physical models are often used in the fields of image processing and computer vision [27][28].

Independent Component Analysis (IAC) is a dehazing algorithm adopted by Fattal's algorithm and MRF method is used to restore the color of the scene [29]. This method is relatively mature in physical model-based processing and has made great progress in processing results, but this method can't deal with large haze scenarios. Fattal project team assumes that the light propagation is not locally correlated with the scene target, estimates the irradiance of the scene and the propagated image. However, this method is based on the input data statistics and requires sufficient color information. When the credible propagated image can't be obtained, the color of the restored image will be distorted to a certain extent [30].

1.1.5. Evaluation method of image restoration effect

The quality of dehaze image is greatly influenced by human visual system (HVS), but in order to make it easier for people to understand and analyze image, a scientific and reasonable image quality evaluation system is very important. There are many methods for evaluating the quality of image processing, but the objective evaluation results for the clarification effect of image dehazing are rare, which are basically limited to subjective visual evaluation. The most commonly used method for haze removal evaluation is the contrast enhancement evaluation method based on visible edge proposed by the French Hautiere's team. However, the problem is that the effect of haze removal is evaluated only from the perspective of image contrast, and the quality of haze removal is not considered from the perspective of image color.

At present, the commonly used evaluation methods of image quality effect after processing refer to the relevant indicators of image quality evaluation, such as mean squared error, Structural similarity, peak single-to-noise, and chromatic aberration. The difference between CIEDE2000 and other indicators can be directly used to evaluate the effect of dehaze image, and the recognition of consistency results is low. Therefore, it is of great significance to study the objective and reasonable evaluation methods of image dehazing algorithm.

According to the degree of demand for reference information, the existing objective evaluation methods basically follow three kinds of methods: full reference, semi-reference and no reference, among which the first two need to use reference images. In contrast, for the specific application of image dehazing effect evaluation, the existing objective evaluation methods are mainly divided into two categories:

One is to measure image contrast only. The contrast enhancement evaluation method, proposed by Hautiere's term, who obtains the contrast image through visible edge detection [31]. On this basis, the contrast enhancement ability of the image is well measured by using the relevant evaluation indicators. However, this method can't accurately assess the existence of over-enhanced images, the other is a comprehensive consideration of both image contrast and color. Global and local contrast are used to measure the contrast enhancement degree of the dehaze image. At the same time, the hue polar coordinate histogram, principal component analysis of RGB image and histogram similarity are used to evaluate the color quality of the image from three aspects, that's restoration ability, color restoration ability and color sense of nature.

In contrast evaluation, the operator and bright channel proposed by Canny team are used to detect the effective edge strength of dehaze image, and histogram similarity is used to measure the color restoration ability of dehaze image, then, the evaluation index of detail reduction coefficient and color reduction coefficient, which is also needle. The contrast and color of the image are evaluated objectively. In terms of measuring image color quality, Xu's group proposed the best color image reproduction model, believing that image color quality mainly depends on the image naturalness and color richness perceived by human vision. After that, in view of the few evaluation methods for dehazing effect and the limitations of existing evaluation methods, Guo team proposed an evaluation method for image sharpening effect. Considering the construction of simulated haze environment and human visual perception, a comprehensive evaluation system of contrast naturalness colorfulness (CNC) is established, and the dynamic adaptive control of the parameters involved in each algorithm is realized to a certain extent. At the same time, it has certain practicability. Because the color of the image is also one of the most remarkable characteristics in the evaluation of dehazing effect, it is necessary to evaluate the image comprehensively from the contrast and color combination of the image. So, it besides evaluating the contrast enhancement effect of the image, we intend to use the color naturalness index (CNI) to prove it. Combining the above methods, the image quality evaluation system has achieved some results in monotony and accuracy, but there is no substantial progress in subjective and objective consistency.

1.1.6. Deep learning for dehazing

There are three ways of deep learning. It includes supervised learning, unsupervised learning and mixed deep learning. Deep learning breaks the limitation of traditional machine learning and signal processing technology based on shallow structure. Thanks to the gradual solution of related non-convex optimization problems, in deep learning has made some breakthroughs in image processing and other fields.

As a depth model of layered non-linear structure in essence, the deep feature representation constructed and learned by it has undoubtedly greatly improved the generalization ability of traditional shallow model [32]. However, the local optimization problems caused by the obvious non-convex optimization objective form hinder the effective implementation of gradient-based backpropagation algorithm. It gets benefit from the improvement of unsupervised pre-training method to optimize the initial point, there are some empirical solutions to this problem.

Based on the following three reasons, in deep learning has developed rapidly. They are the tremendous improvement of chip hardware processing performance, which provides the basis for complex computing of deep network, the explosive growth of data used for training makes it possible to learn complex network, and great progress has been made in the research of machine learning and information processing [33].

There are many image dehazing methods based on deep learning. multi-layer perceptron (MLP) training model is usually used for image dehazing [34]. MLP network can approach any function [35][36][37] with very strong non-linear ability. In addition, dehazing can also be realized based on CNN [38]. This method has been successful in image recognition, mainly because the structure of CNN is very suitable for learning image features, because CNN has the structure of Local Receptive Field [39], which is more conducive to perceptual images, and has much less parameters than multi-layer perceptron network, and is not easy to trap. After fitting, it is more suitable for training depth network [40][41], and achieves certain effect on image dehazing. Especially the image dehazing technology DnCNN [42], which is based on the depth convolution residual learning method, is one of the representative algorithms in the field of image dehazing.

At present, denoising auto-encoder is also outstanding in image dehazing [43][44][45][46][47]. This dehazing algorithm is an unsupervised learning based on neural network. By learning the hidden layer unit to represent the image features, its input and output are relatively easy to obtain, without too much consideration of image size changes, and can learn good data features. However, this model often sets the value of some nodes to zero when the network is input. That is to say, Dropout technology in deep learning mainly adopts unsupervised learning data characteristics to carry out layer-by-layer pre-training [48], rather than directly aiming at dehazing, so even if some methods based on it are improved on dehazing effect. Promotion is also limited.

In 2014, Ian Goodfellow put forward a pioneering GAN model [49], which endows human thinking mode with two main models, they are generation model and discrimination model. The generated model is used for training and learning, and the discriminant model is used to judge whether the generated model is close to reality, until the discriminant model can no longer judge whether the generated model is true or false. In recent years, this technology has been applied to image dehazing and achieved good results [50][51][52][53].

The last kind of image dehazing method based on deep learning [54], combined with a certain neural network structure, uses different deep learning techniques to train dehazing model. Researchers have proposed an adaptive multi-column depth neural network [55] for image dehazing, which is also a self-coding dehazing method. This method has fairly good restoration and dehazing effect for defective and blurred digital images. There are also image reconstruction algorithms such as Trainable Nonlinear Reaction Diffusion (TNRD) [56]. By improving the non-linear diffusion model, the algorithm is more suitable for image restoration.

Most of the above methods based on neural network are superior to traditional dehazing algorithms. From the details of dehaze image to the performance indicators of dehaze image, they are more prominent. With the continuous improvement of the algorithm, deep learning dehazing algorithm will have some technical problems after the number of layers is deepened, such as many layers of network will lead to difficulties in model training, gradients are easy to disperse or explode, and model learning effect is not good. It is still very difficult to further improve the effect of image haze removal. Based on the above situation, this study intends to study image dehazing algorithm based on deep learning technology, and study how to train a better dehazing model, how to improve the training speed and convergence speed of the model. This research field has more practical value.

1.2. Conventional Dehazing Technique

In order to solve the ill-posed problem of single image dehazing, some prior knowledge is usually added. The prior knowledge used in this thesis is contrast of image. The algorithm has three assumptions. Firstly, the contrast of hazy image is lower than that of hazy image. Secondly, the change of transmittance is only related to the depth of object or scene, so the transmittance in local area is nearly constant, and the change of transmittance in adjacent area is smooth except for a few discontinuous pixels. Thirdly, statistical characteristics of the restored image should be consistent with the actual haze-less photo characteristics, since this algorithm is only a contrast enhancement algorithm, in theory, it is not to directly restore haze-less photos, so this hypothesis is introduced to illustrate that this algorithm can achieve the effect of approximate haze removal.

1.2.1. Prior theory

The algorithm of dark channel prior is simple, and the dark channel formula is used, for example as formula 1-3.

$$J^{dark}(x) = \min_{c} \in \{\mathrm{r}, \mathrm{g}, \mathrm{b}\}(\min_{y\in\Omega(x)}(J^c(y))) \tag{1-3}$$

After the dark channel prior algorithm is proposed, most of the research is based on some improvements. One of the starting points of this article is that prior knowledge in previous work can complementary each other to make up for the inapplicability of a single prior feature in some scenarios. By constructing a Random Forest Regressor, the transmission map is estimated by random forest model with various prior features as input. Different from the previous work of biasing image processing, this work applies machine learning algorithm to the dehazing algorithm, hoping to automatically find the appropriate model to estimate the transmission image using a certain amount of training data. It is found that the prior feature of dark channel is indeed the most informative feature by training.

In addition, the way of generating training data affects many algorithms of haze removal using machine learning. In practice, it is difficult to obtain a large number of paired, that's hazy image and haze-less image to train the network. In this method, synthetic images are used as training data using atmospheric scattering model. That collect haze-less photos, and arbitrarily sample 16×16 image blocks from them, then synthesize them into hazy image blocks. The synthesis is based on two hypotheses, one is the image content such as transmittance is independent that the same image content can have different depths, the other is the transmittance is constant in the local region that the pixels in the small image block have the same depth.

1.2.2. Machine learning for transmission map

The convolution neural network is applied to the algorithm of dehazing problem, then estimating transmission map. As a model, the convolution neural network is divided into three layers: 1) feature extraction layer based on max out unit. 2) parallel use of "multi-scale mapping" layer with different size convolution kernels and later "local maximum" layer of Max pooling. 3) use a bilateral ReLU (BReLU) as the "non-linear regression" layer of activation function. As follows. The network structure is simple, the loss function is only MSE loss, and the processing effect is good.

Using the "haze line" of global pixels to estimate the transmission image, a method of estimating the transmission image based on global (whole picture pixels) is proposed. It is based on a prior knowledge that the number of different colors in a haze-less image is much lower than the number of pixels in the image. In other words, Haze-less image can be approximated by a few (hundreds) of colors. In fact, this method of color quantization is quite common in image compression and other applications. For example, after quantifying the image color to 500 different colors, the quality of the image does not change much, as shown in the following figure.

End-to-end dehazing network. In order to achieve end-to-end training and avoid using additional methods to estimate global atmospheric illumination A, a mathematical transformation is first made, and t(x) and A are unified into a variable K(x). In this way, J(x) can be obtained directly by estimating K(x) from the network. Although no significant changes have been found in the processing effect, the network structure has become very simple, as shown in the following figure.

1.3. Summary

The single image dehazing problem is relatively difficult, because it is ill-posed. Researchers usually rely on prior knowledge of dark channels, color attenuation, haze lines and contrast of various images to assist in estimating the transmission image. Transmittance image is very important to the success of dehazing algorithm. Compared with traditional knowledge-based algorithms, machine learning and in deep learning methods are monotonous, but they also lack a deep understanding of the problem itself and the statistical characteristics of images. However, the method based on in deep learning can be understood as the use of a very powerful non-linear model, the use of a large number of hazy/hazy image data pairs to estimate the transmission map, so generally can get results beyond the traditional method. However, the generalization of machine learning algorithm on different data is not well controlled. The algorithm based on dark channel and deep learning