A NEW HAZE IMAGE DATABASE WITH DETAILED AIR QUALITY INFORMATION AND A NOVEL NO-REFERENCE IMAGE QUALITY ASSESSMENT METHOD FOR HAZE IMAGES

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ABSTRACT

In this paper, we propose a new standard haze image database with nearly all kinds of haze situations. Our database includes haze-free images as well as different levels and situations of haze images, such as snowy and extremely serious haze images. Our database also records the related weather and air quality information. Moreover, the database offers a mean opinion score (MOS) for each image as the subjective evaluation of the haze severity. Our database provides ample haze images with various objective and subjective descriptions, and has significantly potential scientific value. Since haze is a reason leading to the degradation of the image quality, obtaining the quality of haze images is also necessary and meaningful. In this paper, a novel no-reference image quality assessment (IQA) method for haze images is also proposed. Our method analyzes the model of haze images to evaluate the quality. The experimental results on the haze database show that our method is consistent with the subjective evaluation.

Index Terms—haze image database, weather and air quality information, mean opinion score, image quality assessment

1. INTRODUCTION

In 2014, extremely severe, persistent haze, which seldom appears in normal days, occurred in Hefei of China. The haze weather attracted our attention and offered us an opportunity to obtain valuable weather images. In this paper, we propose a new haze weather image database by collecting images in same place with different haze weathers. Our database includes the haze-free as well as different levels, from slight to serious, of haze images, which offers a wide range of test images for the researchers. Besides the image data, we also recorded the related weather and the air quality information when the image was taken. Therefore, for each image, there would be objective indicators reflecting the haze severity. What's more, we utilized the subjective image quality method in the development of this database, and obtained the mean opinion score (MOS) [1] of each image as subjective evaluation of the haze severity. To sum up, we not only provide a database with haze images, but also offer the objective as well as subjective haze evaluation.

Our database can be applied to many fields related to image processing, for example, the image quality assessment (IQA). IQA has become an important research direction in computer vision. The ultimate goal of IQA is to achieve a successful IQA method offering accurate quality information for all kinds of images [1]. To achieve such a perfect method, images with various noises are useful and significant. The IQA method needs these images to study for its model. It has been put forward a number of widely accepted and valuable IQA databases with different original and distorted images, such as LIVE [2], CSIQ [3], and TID2008 [4]. However, most of the provided distorted images in these databases are artificial ones, which lead to most of the existing IQA methods only fitting for the images with artificial distortion. However, some natural effects, such as haze, also can cause the degradation of the image quality. An IQA method that can evaluate the images with natural noise is also necessary and important. For example, the haze removal methods can adjust their parameters based on the quality of the haze image to achieve more satisfied visual performance; the outdoor machines can change their internal settings according the image quality to record more accurate data. Therefore, our database that offers adequate and various haze images is important for IOA.

Additionally, in this paper, by analyzing the model of haze images and combining the factors leading to the degradation of haze images, we propose a novel and simple no-reference IQA method to evaluate the quality of haze images. The experimental results on the haze image database show that our method can obtain satisfying performance.

2. THE HAZE IMAGE DATABASE

2.1. Image acquisition



(g) Image "1_7 15"

(h) Image "2 13 10"

(i) Image "1 30 10"

Fig. 1. Example images of our database. (a) is a haze-free image. (b) to (f) are images with different degree of haze. The severity of the haze increases gradually from the (b) to (f). (g) to (i) are the images in special weather conditions. (g) is in rain, (h) is in snow, and (i) is in extremely serious haze.

	Weather	Air quality information						
Image name		SO_2	NO_2	CO	O ₃	PM2.5	101	MOS
		(ug/m^3)	(ug/m^3)	(mg/m^3)	(ug/m^3)	(ug/m^3)	AQI	
(a) 2_4_15	Cloudy	8	14	0.31	31	27	39	5
(b)2_11_10	Sunny	23	19	0.791	26	92	122	3.636
(c)2_28_15	Cloudy	3	17	0.68	24	29	42	2.727
(d)1_17_10	Sunny	16	31	1.498	16	180	230	1.833
(e)1_31_10	Sunny	-	-	-	-	370	414	1.417
(f)2_14_10	Cloudy	7	28	1.179	86	177	227	1.091
(g)1_7_15	Ranny	4	35	1.075	50	95	125	2.333
(h)2_13_10	Snowy	8	15	0.876	28	62	84	2.546
(i)1_30_10	Cloudy	11	44	1.691	129	162	212	1

Table 1 Weather, air quality information and MOS of the images shown in Fig. 1

Our database includes 287 1148×764 PNG images coming from a digital camera, Sony NEX-VG10. In order to obtain sufficient haze images under various conditions, we spent a long time recording the weather images of one place every day. All images in our database were collected at 10:00 am and 15:00 pm every day in Hefei from January 1, 2014 to May 31. Since extremely severe, persistent haze occurred at Hefei during that time, we obtained various and sufficient haze image data. The image in our database was named according to the time when the image was taken, e.g. the name "2_14_10" means that the image was taken at 10:00 am in February 14. Fig. 1 shows some examples of haze images in our database. It can be seen that our database provides a variety of haze situations.

2.2. Weather and air quality information

For each image, we recorded the detailed weather and air quality information, which offer an objective description of the haze severity. Such information was obtained from the nearest "Changjiangzhonglu" monitoring stations automatically in Hefei. Table 1 illuminates the detailed information of the images shown in Fig. 1. Since occasionally the monitoring station would not offer part related information when the image was taken, few of



Fig. 2. The relationship between PM2.5 and MOS. (a) and (b) are the PM2.5 and MOS of all the haze images. The number of 0 to 300 represents January 1 to May 31. (c) is the Scatter plots and fitted curve of MOS versus PM2.5 on haze database.

the air quality information are missing (Table 1"1_31_10"). From Table 1, it can be concluded that the higher the AQI and PM2.5 are, the more serious the haze tends to be.

2.3. Subjective experiments

The air quality information could not offer an accurate description of the haze. In Table 1, even though the AQI and PM2.5 of "2_28_15" is lower than "2_11_10", the haze of "2_28_15" is more serious. Therefore, to describe the haze severity more accurately, the subjective experiments were also conducted.

The experimental environment was set according to Rec. ITUR BT.500-12 [5]. The Single Stimuli (SS) method [5] was used. 13 college students with the age of 20 to 26, who have some basic knowledge on image processing, but have no specific knowledge related to IQA, have participated in the experiments. They were asked to select an image with one of five gradations, which has been described through five categories: "bad", "poor", "fair", "good" and "excellent" (equivalently, with a corresponding score from 1 to 5).

According to the recommendations of [5], the time of accomplishing one experiment by each observer should not exceed 30 minutes. Thereby, in one experiment, only nearly 60 images were evaluated. Each image would cost 15 seconds, including 10 seconds to be observed and 5 seconds to be scored. In this way, the average time for one experiment lasted about 15 minutes. In one experiment, the test images sequence was random, and the subjective evaluations of the first three images were not adopted.

The final values of MOS for each image have been obtained by averaging all quality evaluation for a given image. The MOS of images shown in Fig. 1 is listed in Table 1.It can be seen that the MOS perfectly depicts the haze severity of each image. A higher MOS means an image with better quality or lower haze severity.

In order to reflect the relationship between the objective and subjective description of the images, the PM2.5 and the MOS of all images are illuminated in Fig. 2. It can be seen that our database offers numerous images with different subjective evaluation and different haze severity. To some extent, the subjective evaluation can reflect the objective description.

2.4. Peculiarities of the database

Our database includes nearly all kinds of haze weather situations. First, our database includes the haze-free images (seen in Fig. 1 (a)), which have the lowest related air quality information and the highest MOS. The haze-free image could be used as the reference image to judge the haze removal results. Second, there are various degrees of haze images (shown from Fig. 1 (b) to (f)) in our database. Researchers could comprehensively test their methods with different haze severity in different weather situations on this database. Third, our database uniquely provides some special haze images, such as snowy or rainy haze images (depicted in Fig. 1 (g) and (h)), and extremely serious haze images (illuminated in Fig. 1 (i)), which have potential scientific values.

Each image in our database has detailed descriptions of the haze information, especially has the subjective evaluation. The researchers could choose and utilize images with different situations according to the descriptions easily.

Because our image is continuously collected in one place, it also could be used as a resource to study the environment of Hefei in China.

3. IMAGE QUALITY ASSESSMENT FOR HAZE IMAGES

Evaluating the quality of haze images is significant. However, most traditional IQA methods only performs well on artificial distorted images and achieve unsatisfied performance on haze images. In this paper, a novel noreference IQA method for haze images is proposed. The details of the method are discussed in this section.

3.1. The proposed method

In computer vision and computer graphics, the model widely used to describe the formation of a hazy image is [6]-[8]:

$$I(i, j) = J(i, j)t(i, j) + A(1 - t(i, j))$$
(1)



Fig. 3. Scatter plots and fitted curves of MOS versus scores obtain by IQA methods on the haze database.

Table 2 SROCC of IQA methods on haze database

Database criteria	SROCC		
SSEQ	0.3552		
BRISQUE	0.2492		
The proposed	0.9000		
300	es ed with logistic function		



Fig. 4. Scatter plots and fitted curve of PM2.5 versus scores obtains by our method on the haze database.

where *I* is the observed intensity, *J* is the scene radiance, *A* is the global atmospheric light, and *t* is the medium transmission describing the portion of the light that is not scattered and reaches the camera. (i, j) means pixel (i, j) of the image. *I* is considered to be the distorted information. Since *J* represents the original information, which has the best quality, the reasons leading to the degradation of image quality of *I* are *t* and *A*. Therefore, our method evaluates the haze image quality by analyzing the influence of *t* and *A*.

Based on (1), it can be seen that lower t means fewer original information transformed to the receiving terminal and worse quality of distorted images. According to analyze the images in our databases, we found that lower A results in lower intensity of the image, and images with lower intensity intend to have lower MOS. Therefore, it can be concluded that the values of t and A are proportional to the quality of haze images. Finally, the quality of a haze image R is evaluated as:

$$R = \sum_{i,j} A(i,j) * \sum_{i,j} t(i,j) / W / H$$
 (2)

where W and H indicate the width and height of the image. Since the strategy of [8] to calculate the A and t has low complexity and achieves accurate data, we adopt it in our method.

3.2. The results

In this section, the performances of our method are compared with two state-of-art no-reference IQA methods

on our database. The two IQA methods are No-reference IQA based on spatial and spectral entropies (SSEQ) [9] and Blind/Referenceless Image Spatial Quality Evaluator (BRISQUE) [10]. The results of the Spearman rank order correlation (SROCC) [2] of these methods are listed in Table 2. A higher SROCC means a better method. Fig.3 shows the scatter plots and fitted curves of the scores from the IQA methods versus subjective scores on the haze databases. From Table 2 and Fig.3, it can be seen that our method outperforms other IQA methods and the objective scores predicted by our method correlate consistently with the subjective evaluations. The poor performance of traditional IQA methods also depict the necessity of building database with natural noise, which are useful for training the models of these IQA methods. Fig. 4 shows the scatters plots and fitted curve of the score of our method versus PM2.5 of the haze database. It can be seen that higher scores of our method represents lower PM2.5 and better air quality. Our method could also be used to calculate the air quality.

4. CONCLUSION

This paper presents a new haze image database that includes all kinds of haze images, such as haze-free images, images with different haze levels and some images with special haze conditions. In order to reflect the haze severity, the database also records the related air quality information and the weather of the images. In this paper, the subjective IQA method is applied to the development of the database, and offers a MOS for each image as a subjective evaluation of the haze severity. Additionally, this paper also proposes a novel and simple no-reference IQA method for haze images. Our method analyzes the factors leading to the degradation of image quality to evaluate images. The experimental results on the database demonstrate that our method is consistent with human perception.

We have collected the full year 2014 images. In addition to the released images, the rest images would be added in the database as soon as possible.

5. ACKNOWLEDGENENT

This work is supported by National Nature Science Foundation of China under Grant No.61331020.

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