Robust Image Dehazing and Matching Based on Koschmieder's Law And SIFT Descriptor

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***Abstract* - If two images of the same scene are taken into consideration, then the matching between them is a challenging task. The images which are used for the process of matching undergo geometric and photometric variations. These variations are due to the difference in time at which the images are taken, the difference in camera from which the images are taken and the difference in viewpoints. The matching of outdoor and aerial images is more challenging. Besides geometric and photometric variations, degradation by haze can also be found in outdoor and aerial images. Such degraded images cannot be used to perform robust image matching. Therefore, dehazing of hazy images is necessary. Here a contrast based dehazing technique which is based on koschmieder's law is used to effectively dehaze hazy pair of images. Koschmieder's law based dehazing technique is compared with a dehazing technique which is based on dark channel prior. Koschmieder's law based dehazing technique outperforms dark channel based dehazing technique in terms of speed. Moreover, it is able to produce a visually pleasing result. It is shown that koschmieder's law based dehazing technique is best suited for image matching since it is able to produce more number of feature points for matching than the feature points in dark channel based dehazing technique. In order to detect and describe the feature points for matching, a powerful detector and descriptor called SIFT(Scale Invariant Feature Transform) is used.**

***IndexTerms* - Dehazing, image matching, Scale Invariant Feature Transform(SIFT)**

I. INTRODUCTION

Image matching is the process of comparing images for finding out the similarity between them. If two images of same scene are taken into consideration, then the matching between them is a challenging task. It is because, the images which are used for matching process experience geometric and photometric variations. Geometric variations such as translation, rotation, scale etc and photometric variations which are the variations due to light such as brightness, exposure, blur etc are experienced. These variations are due to the difference in time at which the images are taken, the difference in camera from which the images are taken and the difference in viewpoints. Image matching can be used to detect changes between images, used in cartography using imagery, used to fuse two images etc [12]. Same scene matching is also used in missile tracking and aircraft navigation.

In feature based image matching, the similarity is checked between feature points in both images. Feature points are the interesting or special points in an image. These points vary from their immediate neighbor [8]. In olden days, the process of image matching was very much complicated. It is because humans themselves had to put on effort in extracting the feature points for matching. In this modern era, with the growth of local feature detectors and descriptors, the task of image matching is handled automatically. The process of image matching faces a lot of challenges such as view point variation, illumination, scale etc. In order to overcome these challenges, a local feature detector should extract feature points satisfying several properties such as repeatability, invariance to translation, rotation and scale, invariance to brightness, exposure and blur, invariance to noise etc [8]. Figure 1 shows image matching based on local feature points. In the figure, the feature points are invariant to image rotation.

The matching of similar scenes is challenging. The matching of outdoor and aerial images is more challenging. Besides geometric and photometric variations, degradation by haze can also be found in outdoor and aerial images [12]. Haze is an atmospheric phenomenon. The main cause of haze is particles such as smoke, fog and dust [12]. Haziness in an image will fade the color of the image. Moreover, contrast of an image is reduced. Scattering takes place in a large amount in hazy images and hence the color information is changed. Such degraded hazy pair of images cannot be used to perform robust image matching. Therefore, dehazing of hazy pair of images is required.

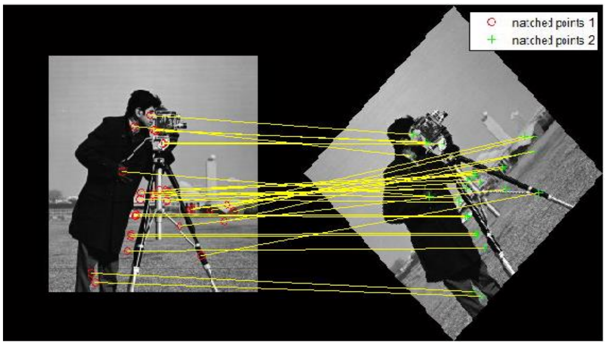

Figure 1 : Image matching based on local feature points

II. RELATED WORKS

This section gives a brief description of several existing works regarding dehazing approaches and local feature detectors.

The early dehazing approaches depend on multiple images, utilize depth map as an additional information or depend on specialized hardware.S. G. Narasimhan and S. K. Nayar *et al.* [1] presents a physics–based model to describe the appearances of images taken in bad weather conditions. The physics-based model makes use of atmospheric scattering models such as attenuation, airlight, wavelength dependence scattering, weather conditions, camera response etc. Here the author addressed the problem of restoring the contrast of degraded images and video. But this dehazing technique suffers from the disadvantage of being relied on multiple images. J. Kopf and B. Neubert *et al.* [2] presents a novel system called 'Deep Photo'. It is used for browsing, enhancing and manipulating casual outdoor photographs. This dehazing technique utilizes depth map as an additional information, which is its disadvantage. T. Treibitz and Y. Y. Schechner *et al.* [3] presents dehazing methods that depend on a polarizer. Here polarizer is useful since the airlight is partially polarized. Here the author determines whether a polarizer really improves visibility of objects in haze. But this dehazing technique suffers from the disadvantage of being dependent on an external hardware, which is the polarizer.

Single image based dehazing techniques are divided into two classes : Physically based dehazing techniques and contrast based dehazing techniques. Kaiming He and Jian Sun *et al*. [4] presents a physically based dehazing technique. It is based on an effective image prior, the dark channel prior. Dark channel prior is used to remove haze from a single input image. The dark channel prior combined with haze model will lead to the estimation of thickness of haze and thus recover a high quality haze free image. The dehazing technique is invalid if the scene objects are similar to atmospheric light and no shadow is cast on them. Moreover, the present dehazing technique is very expensive and time consuming which degrades its performance. In [7], a novel visibility restoration algorithm based on koschmieder's law is introduced. The main advantage of this algorithm is its speed. Here, depth map is not estimated. Haze is removed by maximizing the contrast of degraded regions. The algorithm is controlled by a few parameters and consists in : atmospheric veil inference, image restoration and smoothing, tone mapping. Because of its fast nature, we are using the dehazing technique as described in [7] in our paper.

T. Tuytelaars and K. Mikolajczyk et al. [8] presents a survey on various local invariant feature detectors. Here corner detectors, blob detectors and region detectors are described. It is said that blob like structures can be easily located in scale than in corners. Blob detectors such as Hessian detector, Salient Regions, DoG (Difference of Gaussian) and SURF (Speeded-Up Robust Features) are described. It is said that Hessian detector finds blobs which are not well localized. Salient regions are very costly to compute. Among the blob detectors, the blob detectors such as DoG and SURF are used for efficient implementations. D. Lowe et al. [14] presents an operator called SIFT (Scale Invariant Feature Transform). It is a scale and rotation invariant detector and descriptor. SIFT has got the capability of extracting a large number of feature points. SIFT uses a cascade filtering approach to extract these feature points.The keypoint descriptors are highly distinctive. Keypoints between two images are matched by identifying their nearest neighbours.For matching we are using SIFT, since it is very powerful.

III. DESIGN

Figure 2 shows the design of our implementation.There are two input images which are hazy. Both of them are of the same scene, but taken from different views. Initially, feature points are extracted using SIFT operator in both input images. Then, matching is performed over hazy pair of images to find the number of matches. After that, the input hazy images are dehazed by using a contrast based dehazing technique which depends on koschmieder's law. Feature points are extracted using SIFT operator in dehazed pair of images. Then, matching is performed over dehazed pair of images to find more number of matches.

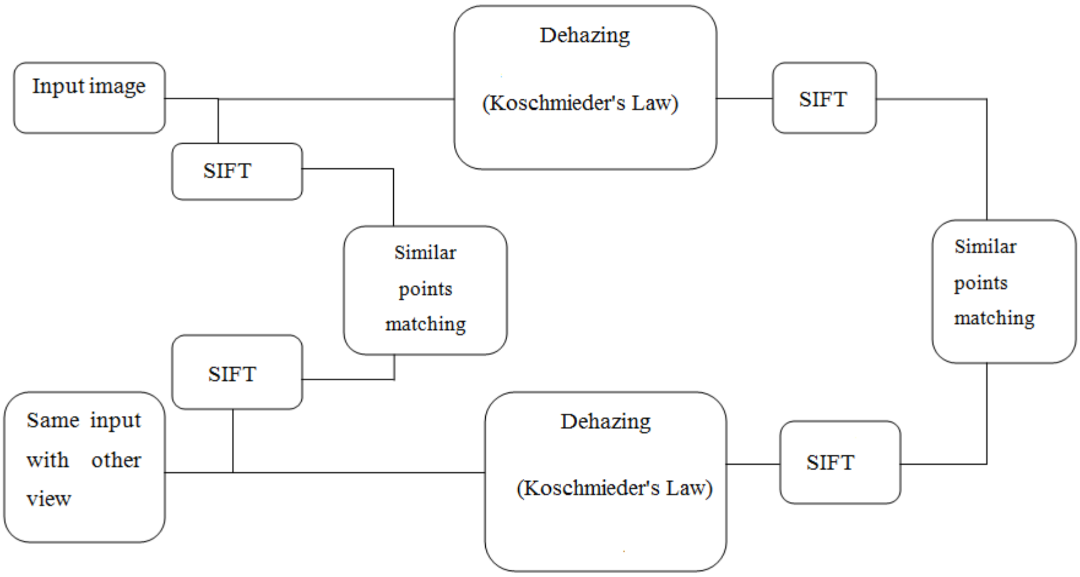

Figure 2 : Implementation Design

Dehazing

Here we use a contrast based dehazing technique based on koschmieder's law as described in [7]. It outperforms other dehazing techniques in terms of speed. As the name suggests, contrast is maximized to remove haze.

Koschmieder's law by introducing atmospheric veil is given by :-

$$I(x, y) = R(x, y) ((1 - V (x, y)))/ Is + V (x, y) \qquad (1)$$

Where I(x,y) is the observed image intensity at pixel (x,y), R(x,y) is the image intensity without fog, V(x,y) is the atmospheric veil, Is is the sky intensity.

The dehazing algorithm consists in : atmospheric veil inference, image restoration and smoothing, tone mapping.

Atmospheric Veil Inference :-

Atmospheric veil V(x,y) is due to the effect of fog. It is white in color. Instead of searching for depth map, atmospheric veil can be inferred. Contrast is increased by maximizing atmospheric veil.

Image Restoration :-

Once atmospheric veil is inferred, the restored image R(x,y) can be obtained by inversing equation (1).

Smoothing:-

Contrast maximization is dependent on atmospheric veil. If atmospheric veil is more, then contrast is increased more. But unfortunately, it will result in increasing noise in image. Therefore, in order to reduce noise, smoothing is performed over restored image.

Tone mapping :-

The restored image is of higher dynamic than original image. Therefore, for better visualization tone mapping is performed.

SIFT :-

In our paper we are using SIFT (Scale Invariant Feature Transform) operator for matching purpose because of its distinctiveness and invariance. Below given is a short description of SIFT as described in [14].

Matching Based on SIFT :-

Matching based on SIFT is divided into several steps :-

- Scale-space extrema detection
- Keypoint localization
- Orientation assignment
- Keypoint descriptor

Scale-space extrema detection :-

The detection of scale-space extrema is accomplished by searching for stable features across all possible scales. The stable features are searched using a continuous function of scale known as scale space. Here difference-of-Gaussian is used as the scale space. The maxima and minima of difference-of-Gaussian images are detected.

Keypoint localization :-

Accurate keypoints are selected based on their stability measures. Keypoints are localized by performing a detailed fit at each candidate location. This is to find out the location, scale and ratio of principal curvatures of accurate keypoints. Here keypoints with low contrast and that are poorly localized along an edge are rejected.

Orientation assignment :-

Here, each keypoint is assigned one or more orientations. Orientations are assigned based on the direction of local image gradients. All operations are transformed relative to the orientation, scale and location of feature points. Hence invariance to these transformations is achieved.

Keypoint descriptor :-

Figure 3 shows the descriptor representation. A keypoint descriptor is created with the help of sample points that lie in a region around the keypoint. Gradient magnitude and orientation at each image sample points is computed for the creation of keypoint descriptor. These are weighted by a Gaussian window. It is indicated by an overlaid circle as shown on the right of figure. These samples are then accumulated into orientation histograms as shown on the right of figure. The length of each arrow represents the magnitude of histogram entry.

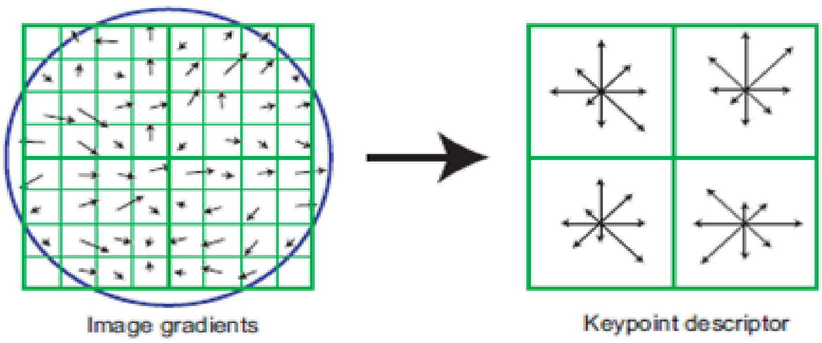

Figure 3 : Descriptor Representation

IV. EXPERIMENTAL RESULTS

The system design has been implemented using MATLAB. MATLAB 7.5 and above versions of it can be utilized. The design is implemented using a windows 7 home basic computer with 64 bit OS and having 4GB of RAM. Here images of size 256x256 is considered. Initially, image matching is performed over hazy pair of images. Then matching is performed over dehazed pair of images to get more number of feature points for matching and hence more number of matches. Below given figures show the results of our implementation.

Figure 4 : Input Hazy Images

Figure 5: Matches Before Dehazing

Figure 6 : Dehazed Image Pair

Figure 7 : Matches After Dehazing

Figure 4 shows the original input hazy images. The hazy images belong to the same scene, but taken at different view points. Figure 5 shows the matches before dehazing.16 matches have been found. Dehazing is done using koschmieder's law. Figure 6 shows the dehazed pair of images. Figure 7 shows the matches after dehazing.400 matches have been found.

V. EVALUATION

The performance of koschmieder's law based dehazing technique is evaluated by comparing it with the dehazing technique based on dark channel [4]. Koschmieder's law based dehazing technique outperforms dark channel based dehazing technique in terms of speed. The koschmieder's law based dehazing takes about 4 seconds while the dark channel based dehazing takes about 20 minutes to produce the output. Images dehazed by using koschmieder's law are pleasing in appearance.In addition to this, koschmieder's law based dehazing technique is able to produce more number of matches than the matches in dark channel based dehazing technique.

Figure 8 : Image Dehazed using Dark Channel Method

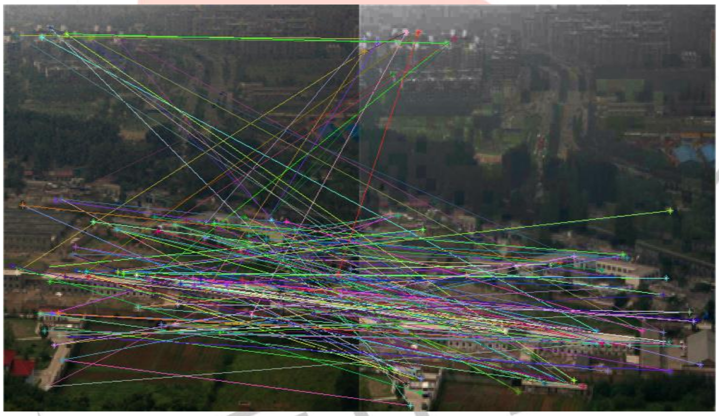

Figure 9 : Matches After Dehazing

Figure 8 shows the image dehazed using dark channel based dehazing technique. Figure 9 shows the matches obtained after dehazing.156 matches have been found.

Dehazing Approaches	Matches Before Dehazing	Matches After Dehazing
Dark Channel	16	156
Koschmieder's Law	16	400

Table 1 : Performance Analysis of Dehazing Approaches

VI. CONCLUSION

Outdoor and aerial images that are taken for matching purpose are often seen as hazy.Therefore dehazing of those images is necessary in order to perform image matching on them.Here a contrast based dehazing technique which is based on koschmieder's law is used to effectively dehaze hazy pair of images.The performance of koschmieder's law based dehazing technique is evaluated by comparing it with the dehazing technique based on dark channel.SIFT(Scale Invariant Feature Transform) operator is used to extract feature points for matching in both the dehazing techniques.Koschmieder's law based dehazing technique outperforms dark channel based dehazing technique in terms of speed.Images dehazed by using koschmieder's law are pleasing in appearance.It is shown that koschmieder's law based dehazing technique is best suited for image matching since it is able to produce more number of matches than the matches in dark channel based dehazing technique.Hence by using koschmieder's law, the goal to effectively dehaze hazy pair of images for the purpose of image matching is achieved.

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