Vision in Bad Weather using IR Cameras-Challenges & Opportunities

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Abstract— ***The visual effects of bad weather are complex. Bad weather produces sharp intensity changes in images and videos that can severely impair the performance of outdoor vision systems. Outdoor vision systems are used for various purposes such as surveillance and navigation. These systems uses a variety of algorithms such as object identification, feature detection, tracking, segmentation and stereo correspondence. These algorithms are adversely affected by bad weather conditions. To make outdoor vision systems robust to different weather conditions we need to model their visual effects and develop algorithms to account for them.***

In this paper, we provide an alternative solution of seeing through bad weather by employing thermal cameras. We studied the various thermal models and how the viewing can be enhanced by mapping the radiations emitted by objects in the scene to an image or video, which removes the obstruction of vision in bad weather conditions. Based on this analysis, we aim to make a compact and portable system which can be applied for object detection and improved visibility in bad weather conditions.

***Keywords*—– Bad weather, infrared, image processing**

I. INTRODUCTION

During low-light and bad weather human vision is badly impaired because of the inability of human eyes to see through it. Computer vision systems employing CCD and CMOS cameras also fails to produce desirable results in the presence of fog, rain, haze, snow and low lightning with graininess, poor color, colored dots, blurriness and low contrast in the captured image or video. Low light cameras with small lux ratings may be able to capture image in low visibility conditions from a distance but the resulting image may be of very poor quality. Outdoor vision systems deployed for various purposes such as surveillance and navigation requires robust detection of image features. Under bad weather conditions, however, the contrasts and colors of images are drastically altered or degraded and it is imperative to include mechanisms that overcome weather effects from images in order to make vision systems more reliable. This also directly impacts the safety of marine, terrestrial and airborne transportation. The table shows the comparative performance analysis of the different imaging sensors in bad weather conditions :

TABLE I
COMPARISON OF IMAGING SENSORS

CAMERA TYPE	VISIBILITY RANGE	LUX RATING(lux)
CMOS	2-3 m	>10
CCD	4-5 m	1.5-5
LOW LIGHT	6-8 m	0.1-1
INFRARED	3-4 m	0.0

There has been growing interest in the vision and image processing communities regarding image understanding in bad weather. Recent work in computer vision proposes to digitally process images to remove the effects of haze, fog, rain and snow[1]. Algorithms have been developed to recover 3D scene structure and to restore clear day contrasts [2] and colors [2] [3] from bad weather images. Most of this work, however, are based on the atmospheric models of scattering[4] [5]. In this paper we present the application of thermal cameras as a novel solution for the improved viewing in bad weather and low light conditions. A thermal imaging camera produces an image based on the differences in thermal radiation that an object emits. These camera can produce clear image in total darkness, through fog, rain and snow. They need no light at all to produce a crisp image in which the smallest of details can be seen.

II. VISION AND BAD WEATHER

Light characteristics such as intensity and color , are altered by the interaction of light with the atmospheric particles. These interactions can be broadly classified as- scattering, absorption and emission [2]. Scattering due to particles suspended in atmosphere is most pertinent to us. Weather conditions can be classified into steady (fog, mist and haze) or dynamic (rain, hail and snow) based on their physical properties and the visual effects they produce in the image or video captured [6].

The constituent particles in steady weather conditions are too small (1-10 µm) to be individually captured by camera. The intensity changes produced at a pixel is due to aggregate effect of a large number of droplets within pixel's solid angle. Hence, the manifestations of steady weather can be clearly described through volumetric scattering models of attenuation and airlight (Middleton 1952;Mc Cartney

1975). In comparison, the constituent particles in dynamic weather conditions (rain and snow) are 1000 times larger (0.1- 10 mm) than steady weather conditions. So, it requires models that can describe the intensity changes produced by individual particles. Various algorithms have been developed for removing the effects of steady weather [1] [2] [3] and dynamic weather [6] from images. Images captured in bad weather have poor contrast and colors. The presence of aerosols in bad weather scenes produces sharp intensity changes in images and videos. In this paper we describe a approach of using thermal cameras to see through poor lightning and bad weather conditions. It will be applicable for both the steady and dynamic weather, thus improving the quality of images captured through them. This will be beneficial to the navigation, transportation, railways and surveillance systems working outdoor where there is no escape from bad weather

A. Digital Simulation Of Bad Weather

The goal is to generate a visually realistic bad weather image from a clear day scene. Bad weather effects of rain, snow and fog are created by directly manipulating the original clear day image by adding a series of noise to it. The added noise creates a feel of the image captured during the bad weather, where we can control the rate of rain streaks, snow streaks adding to the image. Also, we can control the fog added to the image. Different parameters of the texture and diameter of rain and snow streak can be adjusted creating a visual effect of light rain or dense or mild fog.

Rainfall and snowfall consists of a large number of drops falling at high speeds. Each raindrop or a snow streak acts as a spherical lens that refracts and reflects light from a large field of view towards the camera, creating sharp intensity patterns in images. Fig 1 shows the simulated bad weather images.

Fig. 1 Digitally simulated bad weather images

The above digitally simulated images are then analysed for the measurement of the attenuation in the clear day scene, the reduction in the hue, saturation and intensity value of the digitally simulated images authenticates the weather effect added to our test image. Thus, we can conclude that the attenuated image will be the convolution of the true clear day image with the environmental mask. Mathematically, it can be written as-

$$Icap = Wm * Itrue$$

where, Icap is the captured attenuated image, Wm is the weather mask and Itrue is the ideal clear day image, * signifies convolution. Figure 2 shows the measured graphs for the clear day and simulated bad weather image.

III. COMPARING PREVIOUS ALGORITHMS

Prior work of restoring image captured in bad weather is based on atmospheric model. The restoration process considers the process of degradation - atmospheric scattering model[4][5]. Then inverse the process, compensate the distortion and obtain the estimation of de-weathered images.

There are two kinds of method based on this scattering model single image and multiple images weather-effect removal . Restoring scene colors and contrast from a single image is based on various assumptions (or is usually under constrained). Therefore, there are many methods have been proposed on multiple images, which can be divided into two kinds. Some methods [4] require multiple input images of same scene to be taken under different weather conditions. Other methods [3][7][8] obtain multiple images by varying image optics. In practical situations, it is difficult to achieve these conditions. Alternatively, there are approaches where the camera parameters are set in such a way to remove/reduce the effects of bad weather without altering the appearance of rain. Given the finite resolution and sensitivity of camera, a wide range of camera setting (exposure time, F-number, focus settings) can be modeled to produce the same scene appearance. The algorithmic complexity of all these imaging processes is high, which deters their use in the real time system.

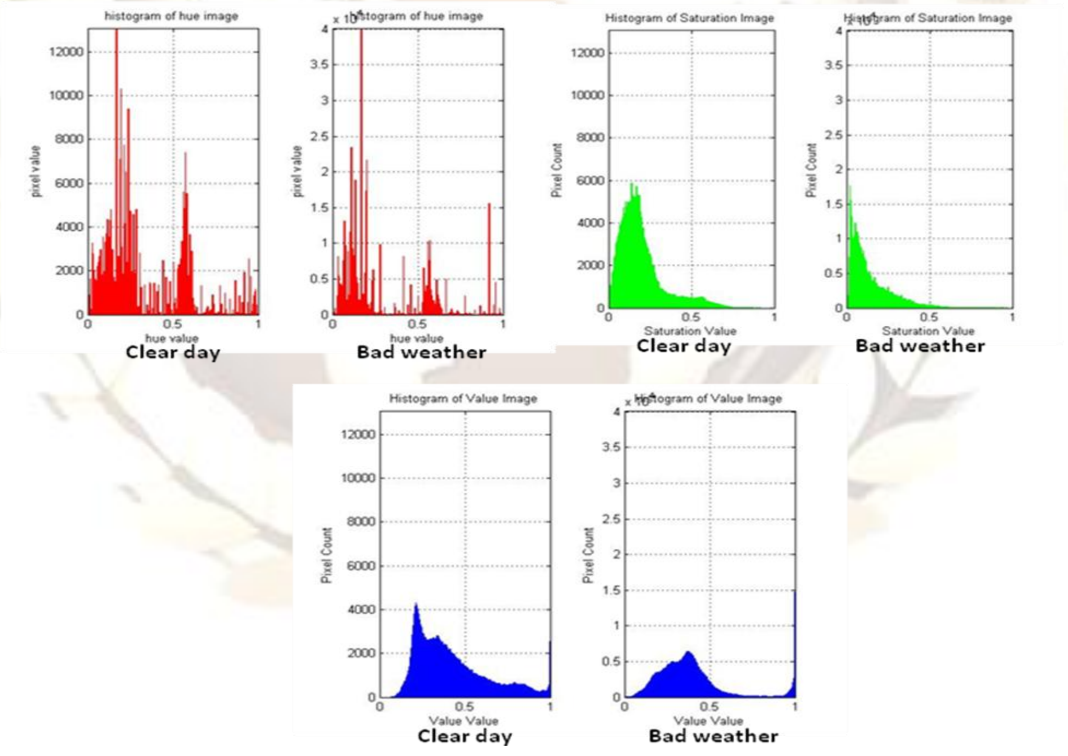

Fig. 2 Schematic diagram showing thermographic measurement principle

IV. Alternative Solution Through Thermal Cameras

In this paper, we propose a novel method of employing thermal cameras as a possible solution in domain of weather-effect free vision. Thermal cameras make images from the heat energy that is around us all the time, not from the reflected visible light, giving us true 24x7 imaging capability without lights or illuminators.

When viewing an object, the IR camera receives radiations not only from the object itself. It also collects radiation from the surroundings reflected via the object surface. Both these radiation contributions become attenuated to some extent by the atmosphere in the measurement path. This description of measurement situation is illustrated in the figure 3 below- where, ε is the emittance of object, Wobj is object temperature, τ is transmittance of atmosphere, Wrefl is reflected transmittance, (1- ε) is reflectance of the object.

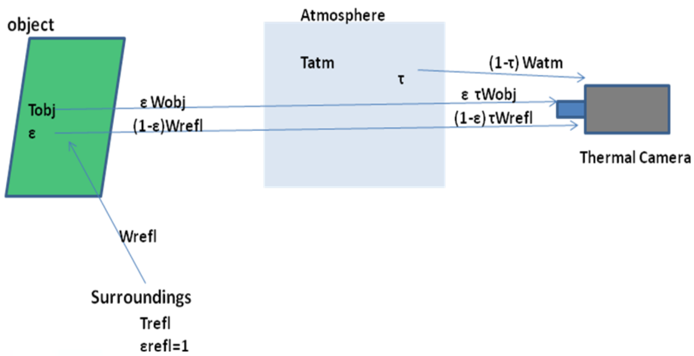

Fig. 3 Schematic diagram showing thermographic measurement principle

Based on the above thermographic measurement principle thermal images are grabbed. This thermal energy penetrates atmospheric obscurants better and farther than visible light, allowing us to see what's out there through haze, smoke , dust and even fog. Thus, thermal cameras have the ability to produce the sharp image of the scene in bad weather in real time which will be displayed on the HUD(head-up display) monitor to the viewer. Fig 4 shows how the thermal camera can be used to see through a fog.

Fig. 4 Few snapshots of using thermal camera in foggy weather

V. CONCLUSIONS

Thermal IR band offers better range performance compared to the visual band. As such, thermal IR cameras are well suited to look through these types of weather. The study suggests that thermal imaging cameras are potentially useful as landing aids for airplanes or as part of driver vision enhancement systems for the transportation and automotive industry. With them we can obtain a sharp image of the bad weather scene where the objects in the scene will be segregated with respect to the thermal radiations emitted by different objects. So, the object emitting larger radiations will be a hot object and a object emitting smaller radiations will be a cooler object. The image obtained therefore, will be divided into - cooler and hotter portions, from which the object of interest could be segregated based on the application domain.

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