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Enhanced Fog Detectiom And Free Space Segmentation For Car Navigation

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ABSTRACT

Free- space detection is a primary task for car navigation. Unfortunately, classical approach have difficulties in adverse weather conditions, in particular in day time fog. In this paper, a solution is proposed thanks to a contrast restoration approach on images grabbed by an in- vehicle camera. The proposed method improves the state-of-the-art in several ways. First, the segment of the fog region of interest is better segmented thanks to the computation of the shortest route maps. Second, the fog density as well as the position of the horizon lines is jointly computed. Then, the method restores the contrast of the road by only assuming that the road is flat and, at the same time, detects the vertical objects. Finally. A segment of the connected components in font of the vehicle gives the free-space area. An experimental validation was carries out to foresee the effectiveness of the method. different results are shown on sample images extracted from video sequences acquired from an in-vehicle camera. The proposed method is complementary to existing free-space area detection methods replying on colour segmentation and stereovision

1-INTRODUCTION

Free-space detection is a fundamental task for autonomous or automated vehicles, since it provides the area where the vehicle can navigate safely. In structured environments, the free-space area is mainly composed of the road surface. This area is either detected based on colour or texture segmentations, deduced from stereovision-based obstacles detection or is a combination of both approaches. However, all these methods have difficulties in foggy weather. Indeed, the contrast is reduced with the distance, which hinders classical segmentation techniques assuming that the colour or the texture of the road is constant, or stereovision techniques based on local correlation from working properly. To solve this problem, one may restore the contrast of the image. Classical free-space detection techniques can then be applied to the restored image. Methods which restore the contrast of images grabbed onboard a moving vehicle under bad weather conditions are hardly encountered in the literature. Indeed, some techniques require prior information about the scene. Others require dedicated hardware in order to estimate the weather conditions. Some techniques rely on two images with different fog intensities and exploit the atmospheric scattering to adequately restore the contrast. Techniques based on polarization can also be used to reduce haziness in the image, these methods require two differently filtered images of the same scene.

Narasimhan and Nayar proposed to restore the contrast of more complex scenes. However, the user must manually specify a location for sky region, vanishing point and an approximation of distance distribution in the image. Recently, different methods have been proposed which rely only on a single image as input and might be used onboard a moving vehicle. First estimate the weather conditions and approximate a 3D geometrical model of the scene, which is inferred a priori and refined during the restoration process. The method is dedicated to in-vehicle applications.

Tan restores image contrasts by maximizing the contrasts of the direct transmission while assuming a smooth layer of air light. Fattal estimates the transmission in hazy scenes, relying on the assumption that the transmission and surface shading are locally uncorrelated. These methods are computationally expensive: 5–7 min with a 600 × 400 image on a double Pentium 4 PC for Tan and 35 s with a 512 × 512 image on a dual core processor for Fattal. Based on the principle proposed in Tan, i.e., the inference of the atmospheric veil, Heetal, as well as Tarel and Hautière have proposed improved algorithms; the latter is fast enough to be used in real-time applications.

The problem of these methods is that the depth map produced by their atmospheric veil inference may be erroneous due to the ambiguity between white objects and fog. A novel approach combining fog detection and contrast restoration is proposed in which is applied to the enhancement of driver assistance systems. Finally, a contrast restoration method able to deal with the presence of heterogeneous fog is proposed in. To solely detect the free-space area, we propose another approach, taking advantage of fog presence.

Following an enhanced fog detection and characterization method, the contrast of the images is restored assuming a flat world. The intensity of all the objects which do not respect this assumption thus becomes null in the restored image, which leads to a very efficient segmentation of the free-space area. This segmentation method is thus inspired from contrast restoration techniques but does not constitute a real contrast restoration method. Indeed, only the road is correctly restored.

2-LITERATURE SURVEY

- **Crisman, J., Thorpe, C.: Unscarf**: A colour vision system for the detection of unstructured roads. In: IEEE International Conference on Robotics and Automation, Sacramento, USA, pp. 2496–2501 (1991)

The problem of navigating a robot vehicle on unstructured roads that have no lane markings, may have degraded surfaces and edges, and may be partially obscured by strong shadows is addressed. These conditions cause many road following systems to fail. The authors have build a system, UNSCARF, which is based on pattern recognition techniques, for successfully navigating on a variety of unstructured roads. UNSCARF does not need a road location prediction to find the location of the road; therefore, UNSCARF can be used as a bootstrapping system. It uses a clustering technique to group pixels with similar colours and locations. It then matches models of road shape to locate the roads in the image. These methods are more robust in noisy conditions than other road interpretation techniques. UNSCARF has been integrated into a navigation system that has successfully driven a test vehicle in many types of weather conditions.

- **Broggi, A., Caraffi, C., Fedriga, R., Grisleri P**.: Obstacle detection with stereo vision for off-road vehicle navigation. In: IEEE Workshop on Machine Vision for Intelligent Vehicles, San Diego, USA, pp. 65–73 (2005)

In this paper we present an artificial vision algorithm for real-time obstacle detection in unstructured environments. The images have been taken using a stereoscopical vision system. The system uses a new approach, of low computational load, to calculate a V-disparity image between left and right corresponding images, in order to estimate the cameras pitch oscillation caused by the vehicle movement. Then, the obstacles are localized by stereo matching and mapped in real world coordinates. Experimental results on sequences taken from a moving vehicle (which participated to the DARPA Grand Challenge 2004) in different unstructured scenarios are then presented, to demonstrate the validity of the approach.

➢ **Soquet, N., Aubert, D., Hautière, N**.: Road segmentation supervised by an extended v-disparity algorithm for autonomous navigation. In: IEEE Intelligent Vehicles Symposium, Istanbul, Turkey, pp. 160–165 (2007)

This paper presents an original approach of road segmentation supervised by stereovision. It deals with free space estimation by stereovision and road detection by colour segmentation. The v-disparity algorithm is extended to provide a reliable and precise road profile on all types of roads. The free space is estimated by classifying the pixels of the disparity map. This classification is performed by using the road profile and the u-disparity image. Then a colour segmentation is performed on the free space. Here is the supervision. Each stage of the algorithm is presented and experimental results are shown.

➢ **Oakley, J.P., Satherley, B.L**.: Improving image quality in poor visibility conditions using a physical model for contrast degradation. In: IEEE Transactions on Image Processing, vol. 7, pp. 167–179 (1998) –

In daylight viewing conditions, image contrast is often significantly degraded by atmospheric aerosols such as haze and fog. This paper introduces a method for reducing this degradation in situations in which the scene geometry is known. Contrast is lost because light is scattered toward the sensor by the aerosol particles and because the light reflected by the terrain is attenuated by the aerosol. This degradation is approximately characterized by a simple, physically based model with three parameters. The method involves two steps: first, an inverse problem is solved in order to recover the three model parameters; then, for each pixel, the relative contributions of scattered and reflected flux are estimated. The estimated scatter contribution is simply subtracted from the pixel value and the remainder is scaled to compensate for aerosol attenuation. This paper describes the image processing algorithm and presents ananalysis of the signal-to-noise ratio (SNR) in the resulting enhanced image. This analysis shows that the SNR decreases exponentially with range. A temporal filter structure is proposed to solve this problem. Results are presented for two image sequences taken from an airborne camera in hazy conditions and one sequence in clear conditions. A satisfactory agreement between the model and the experimental data is shown for the haze conditions. A significant improvement in image quality is demonstrated when using the contrast enhancement algorithm in conjunction with a temporal filter.

➢ **Yitzhaky, Y., Dror, I., Kopeika, N**.: Restoration of altmospherically blurred images according to weather-predicted atmospheric modulation transfer function. Optic. Eng. 36, 3064–3072 (1997)

Restoration for actual atmospherically blurred images is performed using an atmospheric Wiener filter that corrects simultaneously for both turbulence and aerosol blur by enhancing the image spectrum primarily at those high frequencies least affected by the jitter or randomness in a turbulence modulation transfer function (MTF). The correction is based on weather-predicted rather than measured atmospheric MTFs. Both turbulence and aerosol MTFs are predicted using meteorological parameters measured with standard weather stations at the time and location where the image was recorded. A variety of weather conditions and seasons are considered. Past results have shown good correlation between measured and predicted atmospheric MTFs. Here, the predicted MTFs are implemented in actual image restoration and quantitative analysis of the MTF improvement is presented. Corrections are shown also for turbulence blur alone, for aerosol blur alone, and for both together.

➢ **Narasimhan, S.G., Nayar, S.K**.: Contrast restoration of weather degraded images. IEEE Trans. Pattern Anal. Mach. Intell. 25(6), 713–724 (2003)

Images of outdoor scenes captured in bad weather suffer from poor contrast. Under bad weather conditions, the light reaching a camera is severely scattered by the atmosphere. The resulting decay in contrast varies across the scene and is exponential in the depths of scene points. Therefore, traditional space invariant image processing techniques are not sufficient to remove weather effects from images. We present a physics-based model that describes the appearances of scenes in uniform bad weather conditions. Changes in intensities of scene points under different weather conditions provide simple constraints to detect depth discontinuities in the scene and also to compute scene structure. Then, a fast algorithm to restore scene contrast is presented. In contrast to previous techniques, our weather removal algorithm does not require any a priori scene structure, distributions of scene reflectance's, or detailed knowledge about the particular weather condition. All the methods described in this paper are effective under a wide range of weather conditions including haze, mist, fog, and conditions arising due to other aerosols. Further, our methods can be applied to grey scale, RGB colour, multispectral and even IR images. We also extend our techniques to restore contrast of scenes with moving objects, captured using a video camera.

➢ **Schechner, Y., Narasimhan, S., Nayar, S**.: Polarization-based vision through haze. Appl. Optic. Special Issue 42(3), 511–525 (2003)

We present an approach for easily removing the effects of haze from passively acquired images. Our approach is based on the fact that usually the natural illuminating light scattered by atmospheric particles (air light) is partially polarized. Optical filtering alone cannot remove the haze effects, except in restricted situations. Our method, however, stems from physics-based analysis that works under a wide range of atmospheric and viewing conditions, even if the polarization is low. The approach does not rely on specific scattering models such as Rayleigh scattering and does not rely on the knowledge of illumination directions. It can be used with as few as two images taken through a polarizer at different orientations. As a byproduct, the method yields a range map of the scene, which enables scene rendering as if imaged from different viewpoints. It also yields information about the atmospheric particles. We present experimental results of complete dehazing of outdoor scenes, in far-from-ideal conditions for polarization filtering. We obtain a great improvement of scene contrast and correction of colour.

➢ **Narashiman, S.G., Nayar, S.K**.: Interactive deweathering of an image using physical model. In: IEEE Workshop on Color and Photometric Methods in Computer Vision (2003)

Images of scenes acquired in bad weather have poor contrasts and colours. It is known that the degradation of image quality due to bad weather is exponential in the depths of the scene points. Therefore, restoring scene colours and contrasts from a single image of the scene is inherently underconstrained. Recently, it has been shown that multiple images of the same scene taken under different weather conditions or multiple images taken by varying imaging optics can be used to break the ambiguities in DE weathering. In this paper, we address the question of DE weathering a single image using simple additional information provided interactively by the user. We exploit the physics-based models described in prior work and develop three interactive algorithms to remove weather effects from, and add weather effects to, a single image. We demonstrate effective colour and contrast restoration using several images taken under poor weather conditions. Furthermore, we show an example of adding weather effects to images. Our interactive methods for image (de)weathering can serve as easy-to use plug-ins for a variety of image processing software.

3-EXISTING METHOD

Fog detection and free space segmentation are critical components of advanced driver assistance systems (ADAS) and autonomous driving applications. These systems enhance navigation safety, especially under adverse weather conditions like fog, which reduces visibility and increases the risk of accidents. Several existing methods have been developed to address fog detection and free space segmentation, focusing on improving the accuracy, robustness, and real-time performance of these systems. Below are the key approaches.

3.1 Image-Based Fog Detection Methods:

Fog detection is typically approached through image processing techniques that analyse visual features affected by fog. These methods are primarily based on analysing the degradation of image quality caused by fog, such as reduced contrast and colour fading. Common approaches include:

3.1.1 Contrast and Brightness Analysis:

Fog diminishes the contrast and brightness of an image. Methods based on histogram analysis compare the distribution of pixel intensities in clear and foggy images. Low contrast is indicative of fog presence, and threshold-based segmentation is used to detect foggy regions

- Advantages: Simple and computationally efficient.
- Challenges: Sensitive to lighting variations and requires tuning of thresholds.

3.1.2 Dark Channel Prior (DCP):

This technique is widely used for fog removal and detection in computer vision. It assumes that in fog-free images, one colour channel will have pixels with low intensities (dark pixels). Fog adds a homogeneous brightness across the image, making the dark channel less prominent.

- Advantages: Effective for detecting thick fog.
- Challenges: Struggles with low-density fog and may incorrectly classify shadows as fog.

4-Proposed Method

The proposed method aims to enhance visibility in foggy conditions while accurately identifying drivable space for safe car navigation. This system leverages deep learning techniques to improve real-time decision-making in low-visibility scenarios. The approach begins with fog detection and removal, using advanced image dehazing techniques to enhance road visibility. By clearing fog from the input image or video frame, the system improves the clarity and allows for more accurate segmentation of the environment.

Once the image is dehazed, the next step involves semantic segmentation using a pre-trained deep learning model. This model, trained on road scene datasets, segments the image into various classes, such as free space (road), obstacles, pedestrians, and vehicles. This segmentation helps the navigation system distinguish between drivable and non-drivable areas. Labeling the free space is particularly crucial as it provides a clear pathway for the vehicle to follow, ensuring safe navigation.

Additionally, the system integrates distance estimation techniques to calculate the proximity of detected objects. By combining depth information with semantic segmentation, the system provides real-time data on object distances, enhancing situational awareness. Finally, the processed information is displayed on a user-friendly graphical interface, where the dehazed image, segmented regions, and distance metrics are presented, ensuring that the car's navigation system receives clear and actionable insights for driving in foggy conditions.

4.1 Load Deep Learning Model

• **Purpose**: The first step is loading a pre-trained deep learning model. Models like Convolutional Neural Networks (CNNs) or specialized architectures like U-Net are commonly used for segmentation tasks in car navigation systems.

• **Action**: Load the model trained for fog detection and free-space segmentation. This model can detect foggy conditions, enhance the image, and perform segmentation to identify drivable areas.

5-SOFTWARE REQUIREMENTS

5.1 MATLAB

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. MATLAB stands for matrix laboratory, and was written originally to provide easy access to matrix software developed by LINPACK (linear system package) and EISPACK (Eigen system package) projects. MATLAB is therefore built on a foundation of sophisticated matrix software in which the basic element is array that does not require pre dimensioning which to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of time.

5.1.2 Basic Building Blocks of MATLAB

The basic building block of MATLAB is MATRIX. The fundamental data type is the array. Vectors, scalars, real matrices and complex matrix are handled as specific class of this basic data type. The built in functions are optimized for vector operations. No dimension statements are required for vectors or arrays.

5.1.2.1 MATLAB Window

The MATLAB works based on five windows: Command window, Workspace window, Current directory window, Command history window, Editor Window, Graphics window and Online-help window.

Chapter 6

6-RESULTS

In this project we used matlab 2021 software and designed this application. Deep Learning algorithm is trained with 11 different classes including free space. Free space detection is applied to an image to get available space on road for a car

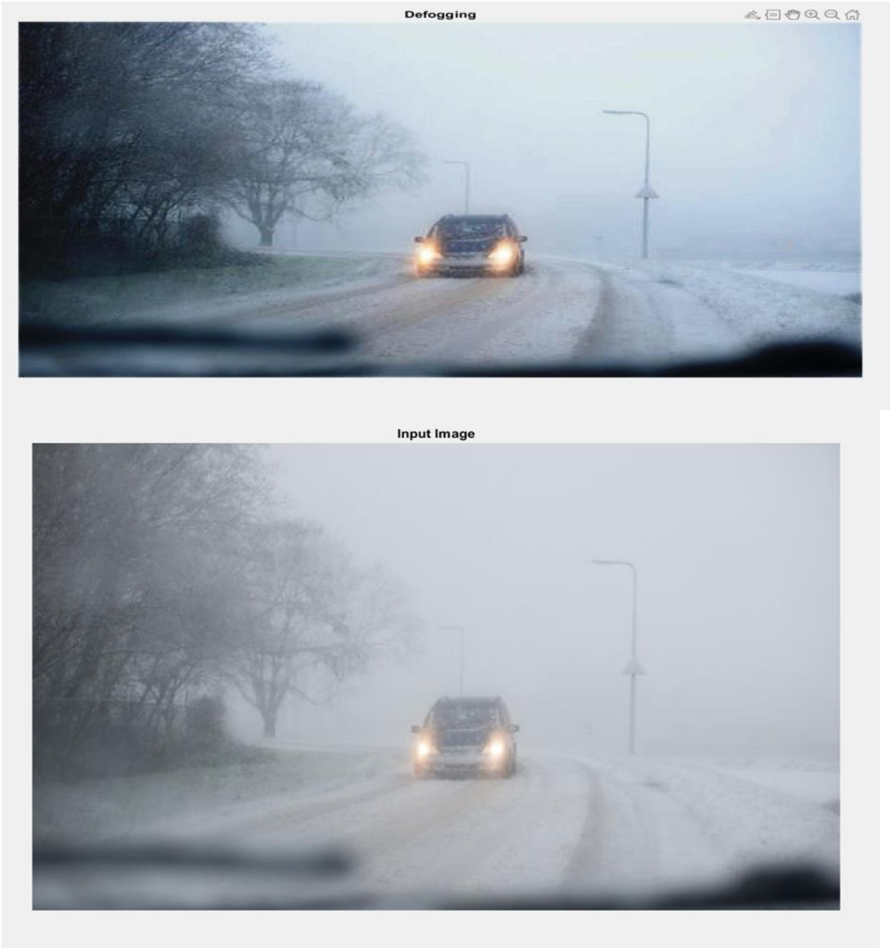

Fig 7.1 Input image with fog present

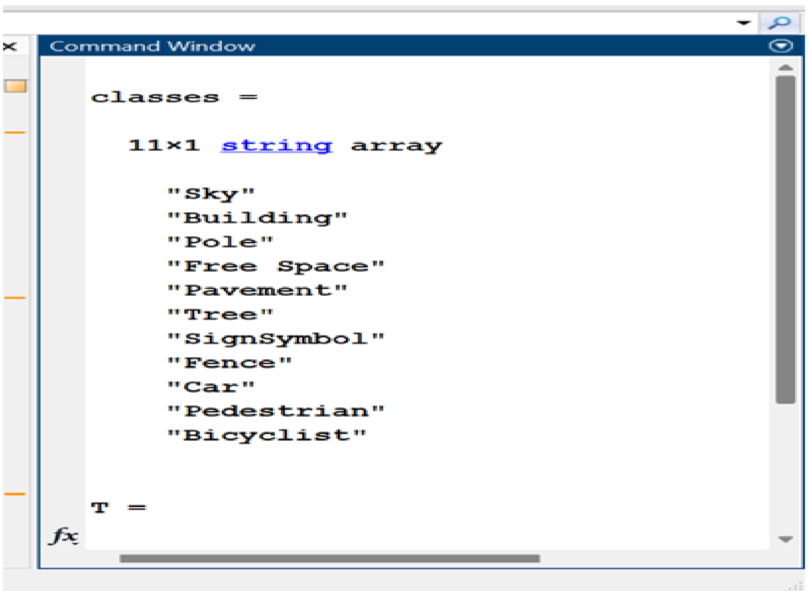

Fig 7.3 Different objects trained to deep learning (including free space)

Fig 7.5 mean distance of objects in image

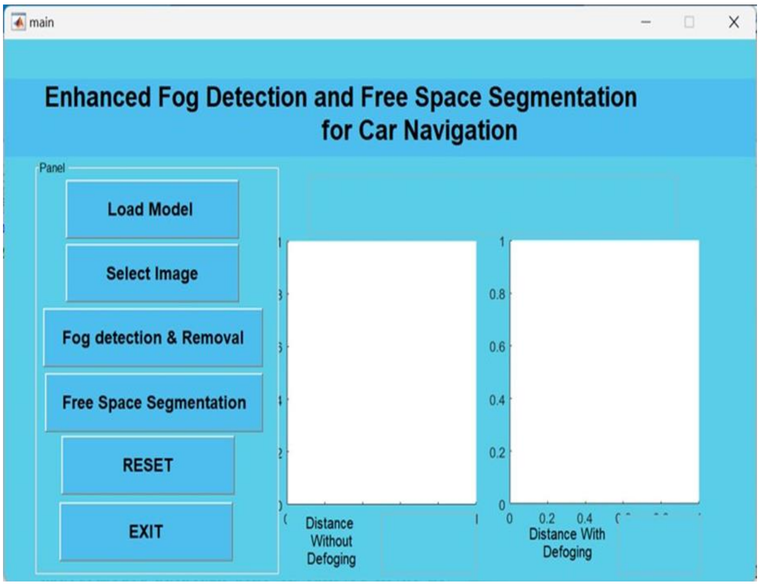

Fig 7.6 GUI prepared for proposed method for easy understandin

7-APPLICATIONS

8.1 Image-Based Methods

8.1.1 Contrast and Brightness Analysis

• Fog detection in affordable Advanced Driver Assistance Systems (ADAS).

• Traffic monitoring and weather detection systems in fog-prone areas.

8.1.2 Dark Channel Prior (DCP)

• Preprocessing for autonomous driving systems to enhance visibility.

• Fog detection and removal in traffic surveillance systems.

8.1.3 Edge Detection and Texture Analysis

• Fog detection for real-time vehicle navigation systems.

• Road safety systems to detect environmental hazards during foggy conditions.

8.2 Sensor-Based Methods

8.2.1 LiDAR-Based Fog Detection

• High-end autonomous vehicles requiring precise navigation in low visibility.

• Premium ADAS for enhanced fog detection and obstacle avoidance.

8-CONCLUSION

A solution was proposed to detect the free-space area in foggy road scenes thanks to a contrast restoration approach. First, the method estimates simultaneously the density of fog and the position of the horizon line in the image, which improves drastically the state-of-the-art in this area. A highly effective fog ROI segmentation method based on geodesic maps computation is proposed as well as a novel joint fog density and horizon line estimation process. Thanks to a simple contrast restoration method, the proposed method is then able to restore the contrast of the road and at the same time to segment the vertical objects and also removes fog.An experimental validation allows figuring out the potential of the method. In the future, we would like to integrate these works in prototypes and test intensively the method, so as to identify some eventual new problems which could appear.

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