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ENHANCED FOG DETECTION AND FREE SPACE SEGMENTATION FOR CAR NAVIGATION

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ABSTRACT

Free-space detection is a primary task for car navigation. Unfortunately, classical approaches have difficulties in adverse weather conditions, in particular in daytime 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 segmentation of the fog region of interest is better segmented thanks to the computation of the shortest routes maps. Second, the fog density as well as the position of the horizon line 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 segmentation of the connected component in front of the vehicle gives the free-space area. An experimental validation was carried 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 relying on color segmentation and stereovision.

INTRODUCTION

Image dehazing is essential in computer vision applications like object detection and tracking, as haze significantly reduces image quality by affecting color and contrast. Haze, caused by atmospheric phenomena like fog, mist, and dust, scatters light and leads to poor visibility, often contributing to traffic accidents. The presence of fog not only reduces contrast but also distorts visual perception, making it challenging to analyze images captured in such conditions.

To address this, various dehazing algorithms have been developed, with Dark Channel Prior (DCP) being one of the most widely used techniques. DCP estimates the transmission map, which helps in haze removal, but suffers from high computational complexity and processing time. This work introduces an improved dehazing approach by refining the DCP transmission map using Simplified Dark Channel Prior (SDCP) along with adaptive and edge-preserving filters. The proposed method enhances scene radiance efficiently, ensuring high-quality haze-free images with minimal computational load.

Once the haze is removed, an edge detection algorithm is applied to enhance object visibility, followed by a simplified object detection algorithm. The method focuses on detecting horizontally aligned wheels, improving detection accuracy and speed compared to previous approaches. Unlike existing techniques that impose strict constraints on object shape and size, the proposed algorithm is more flexible and efficient. The result is a clear, high-contrast image that improves object recognition, making it suitable for tracking, navigation, and surveillance applications.

LITERATURE SURVEY

1.Image Processing-Based Approaches:

- He et al. (2010) introduced the Dark Channel Prior (DCP) algorithm, which estimates fog density by analyzing image contrast. However, DCP struggles in dense fog conditions where light scattering is excessive.
- Ancuti et al. (2013) proposed multi-scale fusion techniques, which enhance foggy images by combining different exposure levels. Despite improvements, real-time implementation remains a challenge.

2.Machine Learning & Deep Learning-Based Methods:

- Hassan et al. (2019) utilized Convolutional Neural Networks (CNNs) to classify fog levels from real-world traffic images, achieving higher accuracy than traditional image processing methods.
- Li et al. (2021) implemented a Vision Transformer (ViT)-based fog detection model, which significantly improved generalization across different fog intensities but required substantial computational resources.

3.Sensor-Based Fog Detection:

- LiDAR and radar-based fog detection methods have been explored to measure visibility distances directly. Studies by Zhao et al. (2020) show that sensor fusion techniques combining LiDAR and thermal cameras improve fog detection accuracy.
    - Recent advancements by Wang et al. (2022) incorporate transformer-based networks for semantic segmentation, achieving better visibility adaptation in foggy conditions.

PROPOSED SYSTEM

The system architecture is depicted in the figure below, illustrating the input, flow of key steps, stages and processes in the accelerated Object detection system.

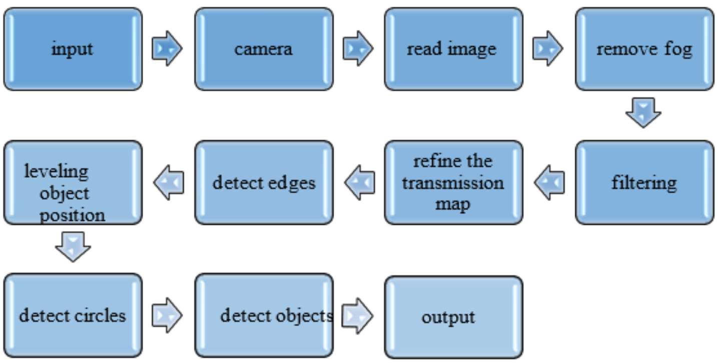

Figure.1 System architecture

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1.Fog Removal Approach

Fog is a serious problem as it is one of the main factors of traffic accidents each year. Many accidents, including fatal ones involving multiple Objects, occur during winter, especially when fog reduces visibility to near or less than 50 meters. The fog removal and Object detection methodology developed in this thesis can assist traffic management systems to identify areas with incidents or heavy traffic in areas with existing cameras.

In the proposed system, the time required to remove fog from an image is approximately 30% of the entire time of executing the complete system (both stages combined). Fog removal is a crucial part of this work, as the failure rate to detect Objects can reach up to about 30%, when circle detection is performed without fog removal.

The equation that describes fog formation in a foggy image is:

$(x) = J(x)t(x) + A(1 - t(x))$ (27)

J(x): clear mage as the required output image A(x): atmospheric light (air light)

I(x): foggy image as input image t(x): transmission map

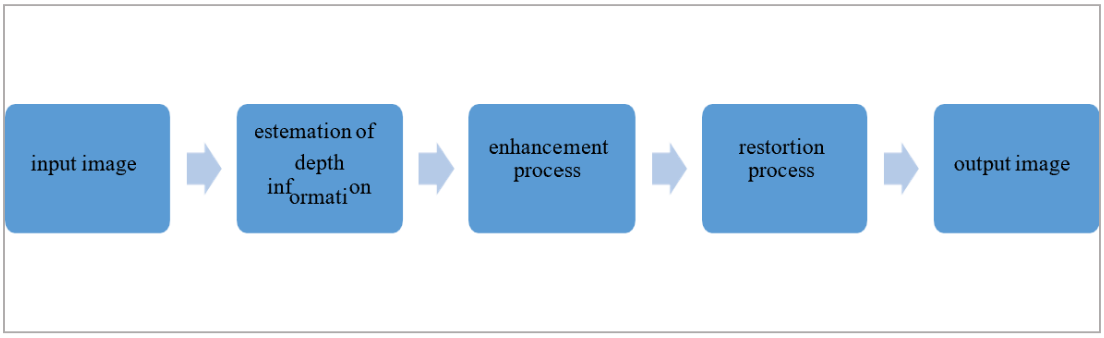


Figure.2 Fog removal Block Diagram

2.Dark Channel Prior

Dark Channel Prior (DCP) is used as a base line for the proposed fog removal algorithm. Initially, the transmission map is defined using the DCP technique; subsequently, the transmission map is refined with the aid of a Simplified Dark Channel Prior (SDCP) using a set of filters consisting of the Proposed Adaptive Filter and an edge-preserving filter. Next, the refined transmission map is used to modify the scene radiance as the fog is removed. Although, the Dark Channel Prior is an efficient method to remove fog and enhance image contrast, it suffers from lengthy execution time, computational complexity and large memory requirement. The fog removal method proposed here, is fast and has negligible image degradation when used as input for the subsequent stage of Object detection. The quality of the fog-free image is observed using the Sobel operator to ensure that during the enhancement process, the edges and the main features of the Object are clearly visible and are not adversely affected, in order to be able to properly detect the edges and circles.

Figure.3 original image

Figure.4 image with fog

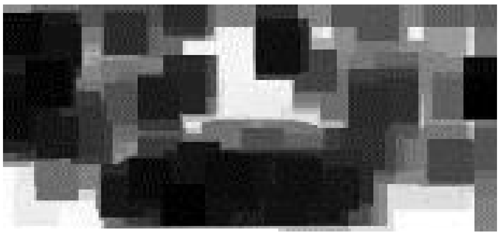


Figure.5 The corresponding dark channel

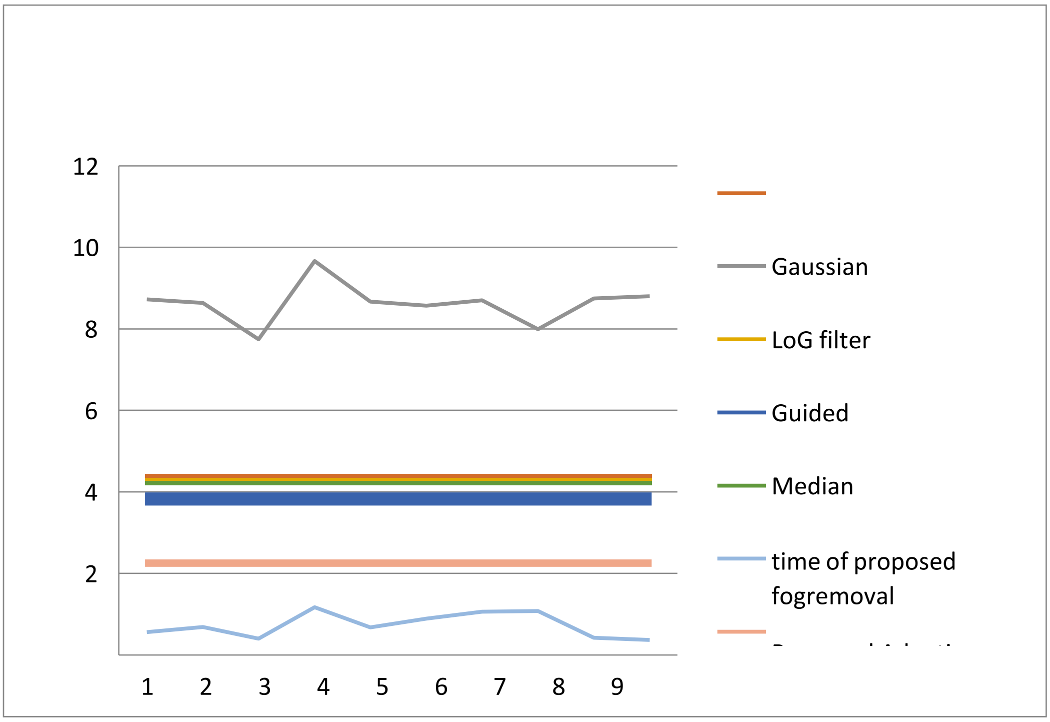


Figure.6 Comparison of different filters

STIMULATION RESULT

MATLAB GUI consists of a structured layout designed for image processing or signal analysis. At the top, there are four empty axes (plot areas) meant to display images or graphical results. Below these axes, several buttons are arranged in a grid format, each corresponding to a specific function. The "Browse" button is likely used to upload an image, while other buttons, such as "Bi-Orthogonal," "Colour Conversion," "Low-Rank Estimation," "Restoration," "Plane Separation," "Structure Sparsity," and "Validation," suggest various processing techniques related to image transformation, filtering, and evaluation. The user can sequentially apply these techniques and visualize the results in the axes above. The structured design ensures an intuitive workflow, where users first load an image, apply transformations, and validate the output.

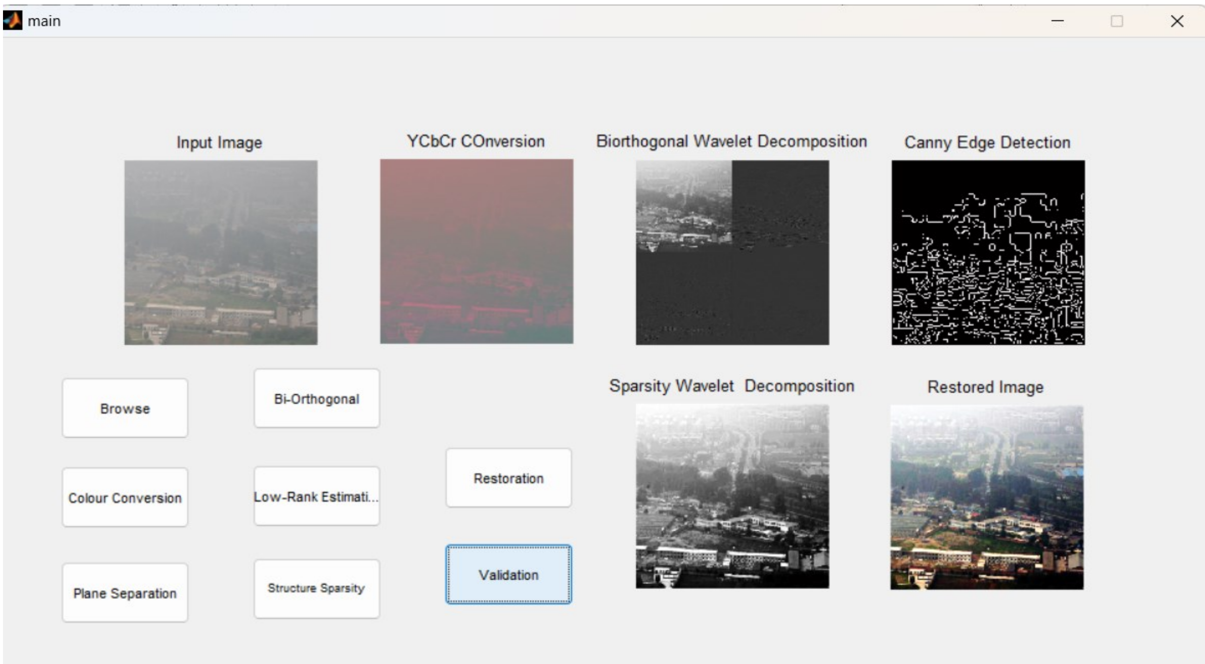
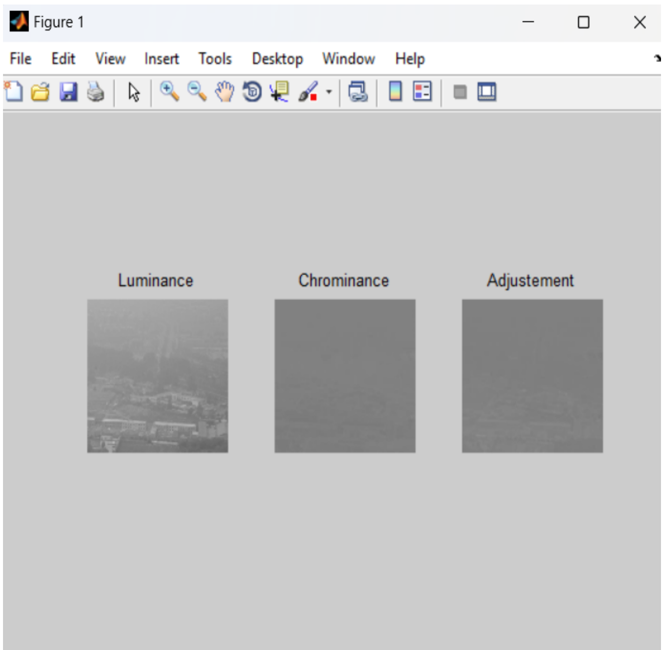


Figure.7 Enhanced foggy image




```
>> main
MSE:
    50.8825

PSNR:
    71.5301

Entropy
     5.5970

>> main
MSE:
    10.9345

PSNR:
    86.9060

Entropy
     5.9638
```

Figure.8 Separation of YCbCr

Figure.9 Validation output

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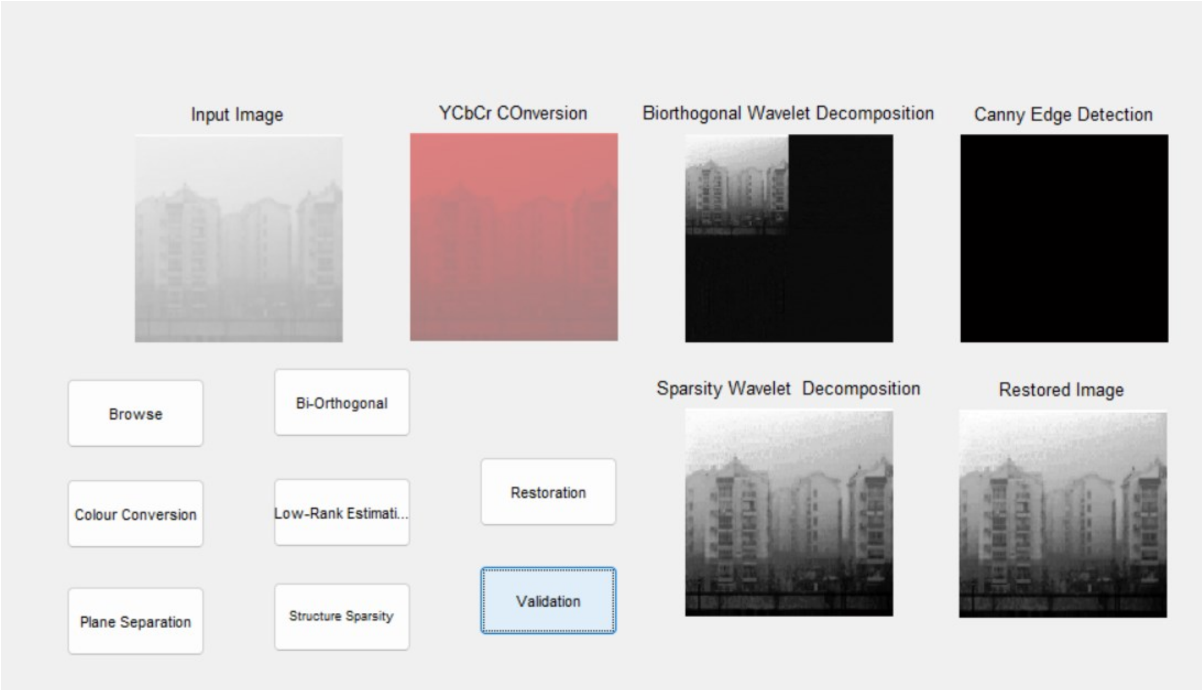

Figure.10 Enhanced fogy image test 2

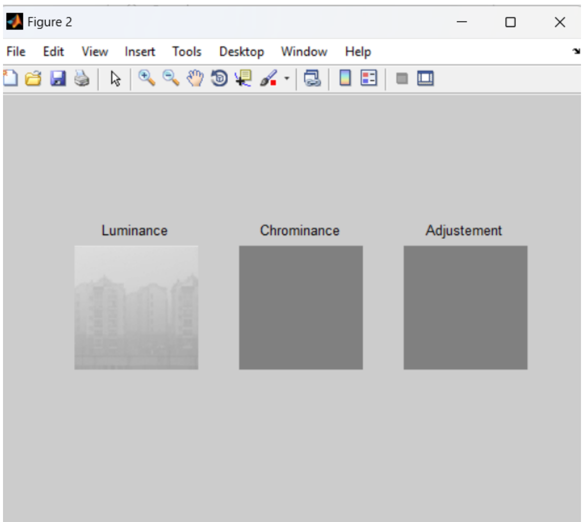

Figure.11 Separation of YCbCr

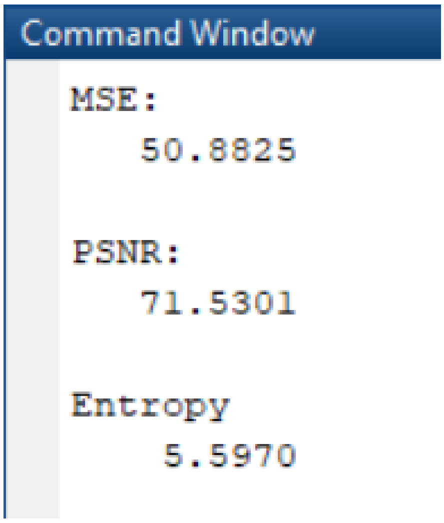

Figure 6.1.7 Validation results

ADVANTAGES

Improved Safety:

- Reduced Collisions: Enhanced fog detection can alert drivers to hazardous conditions like reduced visibility, allowing them to adjust their speed and driving behavior accordingly, potentially preventing accidents.

- Obstacle Detection: By segmenting free space, the system can identify potential obstacles like pedestrians, vehicles, or stationary objects hidden by fog, providing crucial information for collision avoidance systems.

Enhanced Navigation:

- Improved Route Planning: Real-time fog detection can be integrated into navigation systems to dynamically adjust routes, suggesting alternate paths that avoid fog-affected areas.
- Better Lane Keeping: Free space segmentation can help lane keeping assistance systems by accurately identifying lane boundaries even in foggy conditions, improving lane centering and preventing unintended lane departures.

Driver Assistance:

- Fog Warnings: Systems can provide visual or auditory warnings to drivers about the presence and severity of fog, alerting them to potential hazards.
- Head-Up Displays: Enhanced fog detection and free space segmentation can be integrated into head-up displays (HUDs) to provide drivers with real-time information about road conditions and potential hazards.

APPLICATIONS

Advanced Driver Assistance Systems (ADAS)

ADAS includes safety features such as lane departure warning, forward collision warning, and adaptive cruise control. These systems rely on environmental perception to assist drivers in maintaining control and avoiding accidents.

Autonomous Vehicles

Self-driving cars require precise environmental perception for safe navigation. Fog detection helps identify low-visibility conditions, allowing the vehicle to adjust speed and route accordingly.

Traffic Management Systems

Real-time fog detection data plays a vital role in traffic management by identifying hazardous road conditions. Traffic control centers can use this data to adjust signal timings, issue warnings to drivers, and deploy emergency services when necessary. Accurate fog detection helps reduce accident risks by informing drivers of potential dangers in advance.

CONCLUSION

The fog was removed from the input images and the edges and circles were successfully detected in each side-view image. The incorporation of these algorithms and the adaptive histogram equalization techniques can be used to compensate for the human vision in difficult driving conditions. The effect of the environmental factors and the effect of other obstacles in different driving conditions can be improved in such a way that it helps the driving in difficult condition and thus to save the human lives. A simple single-image haze removal algorithm has been proposed in this research by introducing an edge-preserving decomposition technique to estimate a new transmission map in a hazy image and recover the scene depth in a quick and efficient way.

FUTURE SCOPE

The future scope of "Enhanced Fog Detection and Free Space Segmentation for Car Navigation" is vast, with potential advancements in autonomous driving, sensor fusion, and AI-driven navigation. Integrating this system with self-driving cars can significantly improve road safety in low-visibility conditions by providing real-time fog detection and adaptive routing. Advanced sensor fusion, combining LiDAR, radar, thermal imaging, and cameras, can enhance accuracy, while AI and deep learning models can optimize detection and segmentation efficiency. Furthermore, the system can contribute to smart transportation networks by sharing real-time fog data with other vehicles (V2V) and traffic infrastructure (V2X), improving road safety and reducing accident risks. Future developments could also include augmented reality (AR) windshield displays, providing drivers with enhanced visibility in foggy conditions. Additionally, large-scale real-world testing and collaborations with automotive manufacturers can lead to the deployment of this technology in commercial vehicles, making it a crucial component of next-generation intelligent transportation systems.

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