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Research Paper

REAL-TIME DETECTION AND REMOVAL OF RAIN, FOG, AND HAZE USING OPENCV FOR TRAFFIC SAFETY

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ABSTRACT

Rain, fog, and haze are atmospheric phenomena that significantly reduce visibility, especially during adverse weather conditions. These weather conditions pose a substantial risk to road safety, as they can impair the vision of drivers and lead to accidents. Detecting and removing rain, fog, and haze from images captured by traffic cameras or vehicle-mounted sensors can significantly enhance visibility, helping drivers navigate safely and prevent accidents. Traditional systems often rely on image processing techniques and filters. These methods attempt to enhance visibility by reducing the impact of rain streaks, fog, or haze on images. However, these traditional techniques are often limited in their effectiveness, especially in real-time applications and varying weather conditions. Hence, the need for a robust system for rain, fog, and haze removal in the context of traffic safety is paramount. Accurate and real-time detection of these weather conditions, coupled with effective removal techniques, can enhance driver visibility, reduce accidents, and save lives. These systems are especially crucial for autonomous vehicles, where clear and unobstructed vision is vital for safe navigation. Therefore, this research aims to build a system with OpenCV, a popular open-source computer vision library. OpenCV, with its rich set of functions and algorithms, provides a robust platform for developing rain, fog, and haze detection and removal systems. It offers various image processing techniques, including filtering, morphological operations, and machine learning algorithms that can be utilized to address these challenges. By implementing intelligent algorithms in conjunction with OpenCV, it's possible to create efficient and accurate solutions for real-time applications, aiding in the prevention of traffic accidents during adverse weather conditions.

1.INTRODUCTION

Detecting and mitigating the impact of adverse weather conditions such as rain, fog, and haze in the context of traffic safety using OpenCV involves a multifaceted approach. First, images or video frames are captured from cameras, typically mounted on vehicles or at strategic locations. These images often suffer from reduced visibility and image degradation due to the weather conditions. The acquired data undergoes preprocessing to enhance image quality through noise reduction and contrast adjustment. Following preprocessing, image segmentation techniques are applied to isolate critical objects in the scene, such as vehicles and pedestrians. The system then identifies the type and severity of the weather conditions using advanced computer vision methods, enabling it to determine whether it's dealing with rain, fog, or haze. Depending on the weather condition, specific image enhancement techniques, such as de-raining or dehazing, are employed to restore image clarity. Object recognition and tracking algorithms then identify and monitor objects on the road. With an improved view of the environment, the system can make informed decisions, such as detecting potential hazards, lane markings, and calculating safe following distances. If risks are identified, warning systems are triggered, which can include alerts for the driver or even vehicle control adjustments to prevent accidents. The implementation of this system combines classical computer vision and machine learning methods, and OpenCV is instrumental in handling image processing and computer vision tasks. The end result is an Advanced Driver Assistance System (ADAS) that significantly enhances road safety by providing drivers with improved visibility and timely warnings, particularly in challenging weather conditions, ultimately reducing the likelihood of traffic accidents.

2. LITERATURE SURVEY

Fog has a great impact on the application of visual recognition in intelligent transportation. Dense fog will lead to system imaging blur and recognition failure. Images taken by image sensors in poor weather environments such as fog, rain, and haze will have serious degradation problems, which brings many difficulties in extracting useful information from images and has an important impact on the application of remote sensing, target detection, intelligent transportation, and other fields [1, 2]. The research of image defogging has received widespread attention. The existing image defogging algorithms are mainly divided into enhancement algorithms, restoration algorithms, and deep learning algorithms.

The enhanced defogging algorithm improves the image quality through image enhancement technology, mainly including adaptive histogram equalization [3, 4], wavelet transform [5, 6], homomorphic filtering [7], and Retinex enhancement [8–10] algorithms. The adaptive histogram equalization defogging algorithm [3, 4] is an improvement on the basic histogram algorithm, which can indistinguishably improve the image contrast, suppress the slope of the transformation function to some extent, and avoid the phenomenon that rising too fast resulting weak image contrast and oversaturation. However, such methods will amplify the noise in the image when there is a lot of noise in the image. The wavelet transform method divides the image into high-frequency region and low-frequency region and uses the enhancement method for the high-frequency region to achieve the purpose of image defogging by improving the image contrast [5, 6], but it is not suitable for the situation of too bright or too dark and uneven illumination. The homomorphic filtering algorithm composes the illumination component and reflection component of the image, respectively, and processes them in the frequency domain, highlighting the details by enhancing the high-frequency information of the image [7]. It can effectively solve the problem of uneven illumination, but the Fourier transform used causes high computational complexity. The defogging algorithm based on Retinex generally adopts the multiscale Retinex with color restoration (MSRCR) method, which can obtain good defogging effect to a certain extent, but the defogging effect in dense fog scene is not ideal [8–10]. Thanh et al. successively proposed single image dehazing based on adaptive histogram equalization and linearization of gamma correction [11] and single image dehazing with optimal color channels and nonlinear transformation [12]. The method is fast and effective, and the processed image is better than the comparison algorithm in visual and objective indexes.

Restoration defogging algorithms mainly include defogging algorithms based on partial differential equations [13, 14] and defogging algorithms based on prior knowledge [15–25]. The defogging algorithm based on partial differential equation uses multiple images to realize image defogging according to the polarization characteristics of light. Wu et al. [13] and Guo and Meng [14], respectively, proposed a series of improvement measures for the partial differential equation model. The defogging algorithm based on prior knowledge infers the cause of image degradation based on assumptions or prior information and estimates the atmospheric light and transmittance based on the atmospheric scattering model to obtain a fog-free image. The most typical one is the dark channel prior defogging algorithm. The dark channel prior defogging algorithm proposed by He et al. [15] has better effects in close and dark areas, but there are problems with distortion and poor defogging effects in distant and bright areas. Yan et al. proposed the bright channel prior [16], which uses the combination of bright channel and dark channel prior to achieve image deblurring, but did not consider the influence of different depths of field on the dehazing effect. Gao et al. proposed a far and near scene fusion defogging algorithm based on the prior of dark-light channel, and the saturation and sharpness of the image have been improved to a certain extent [17]. Yang et al. proposed adaptive haze estimation and transmittance estimation algorithms and achieved a certain dehazing effect [18, 19]. However, there is oversaturation in areas where dense fog and mist change drastically. Zhu et al. proposed a color attenuation prior. The depth of field information is obtained based on this prior, but the sample collection process of this method is difficult, and the theoretical basis is slightly lacking [20]. Fan et al. successively proposed an adaptive defogging algorithm based on color attenuation [21], single image defogging algorithm based on three-region division [22], an iterative defogging algorithm based on pixel-level atmospheric light map [23], and image defogging algorithm based on sparse representation [24]. The sharpness and contrast of the image after defogging are greatly improved. Kumar et al. proposed a region-based adaptive denoising and detail enhancement method, proposed the autocolor transfer method to strengthen the dark regions of the hazy image, and also considered the variation in haze levels in different regions of the image for adaptive adjustment [25].

The deep learning defogging algorithm achieves defogging by training the model. It has a good defogging effect, but it requires a lot of calculation and needs to build a large dataset [26]. Cai et al. proposed to use the DehazeNet convolutional neural network to estimate the transmittance of the fog map, but the convolutional neural network takes a long time and has poor real-time performance [27]. Luan et al. proposed a classification algorithm based on a learning framework, using a support vector regression model to obtain accurate transmittance, but the feature extraction process is complicated [28]. Liu et al. designed an end-to-end convolutional neural network GridDehazeNet for image defogging and realized multiscale estimation based on attention [29]. Such algorithms require a large amount of datasets during the training process and are prone to overfitting. It is suitable for a single scene and depends too much on the foggy images and nonfoggy images in the datasets. The defogging effect in the real scene is poor.

3. PROPOSED SYSTEM

Detecting and removing rain, fog, and haze to avoid traffic accidents is an important research area in computer vision and image processing. This type of research work typically involves several steps and techniques, often implemented using the OpenCV library, among others. Here's a general procedure for conducting such a research work:

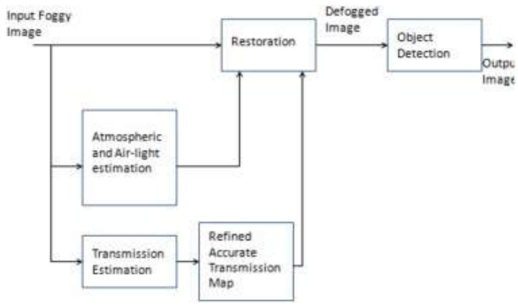

Figure 4.1. Proposed System model.

Step 1: Problem Statement

The problem at the core of this research is to address the challenges posed by adverse weather conditions such as rain, fog, and haze in the context of road safety. Inclement weather conditions significantly reduce visibility on the road, increasing the risk of accidents. These conditions can obscure important visual cues, impairing the ability of drivers and automated driving systems to make timely and accurate decisions. Therefore, the objective of this research is to develop effective techniques for detecting and removing rain, fog, and haze from images and video streams, thereby enhancing visibility and reducing the likelihood of traffic accidents.

Step 2: Data Collection

Data collection is a critical phase in this research as it forms the foundation for developing and evaluating the detection and removal algorithms. To create a robust and representative dataset, it is necessary to gather images and videos that encompass a wide range of weather conditions. This can be done by collecting data from various sources, including publicly available image and video repositories, as well as by capturing new data specifically for the research.

For the dataset to be meaningful, it should include diverse scenarios, covering different levels of rain, fog, and haze. Additionally, it should encompass various environmental settings, such as urban and rural roads, highways, and different times of day. By including both daytime and nighttime footage, the dataset becomes more comprehensive and can be used to validate the algorithms' performance under different lighting conditions.

Moreover, it's essential to capture clear images or videos as reference points. These clear images represent the ideal visibility conditions against which the effectiveness of the rain, fog, and haze removal algorithms can be evaluated. Annotating the dataset is also important, as it helps in identifying regions affected by adverse weather conditions. Annotations can take the form of bounding boxes or masks indicating the areas where raindrops, fog, or haze are present.

Step 3: Preprocessing

Data preprocessing is a critical step in any computer vision research, and this project is no exception. The collected data needs to be prepared for subsequent analysis and algorithm development. Several preprocessing steps are typically undertaken to ensure that the data is in a suitable format for further analysis.

One essential aspect of data preprocessing is resizing the images or videos to a consistent resolution. This ensures that all data samples have the same dimensions, making it easier to apply algorithms uniformly across the dataset. Normalization is also important to ensure that the data is on a common scale and to remove any variations in lighting or color that might affect the algorithms' performance.

Additionally, data annotation is crucial for this research. Annotating the dataset involves labeling the regions in the images or video frames where rain, fog, and haze are present. This is typically done by creating masks or bounding boxes around the affected areas. Properly annotated data is essential for training and evaluating the detection and removal algorithms accurately.

Furthermore, the preprocessed data should be divided into training, validation, and test sets. The training set is used to train the machine learning models, the validation set is used for hyperparameter tuning and model selection, and the test set is reserved for evaluating the algorithms' performance on unseen data.

Data preprocessing is a crucial step that sets the stage for the subsequent stages of the research, including rain, fog, and haze detection and removal.

Step 4: Rain, Fog, and Haze Detection

Detecting rain, fog, and haze in images and video frames is a fundamental component of this research, as it provides the basis for deciding where and how to apply the removal techniques. Several techniques can be employed for this purpose, depending on the characteristics of the weather condition being addressed.

One approach to rain detection is to analyze the characteristics of raindrops in the images. Raindrops typically appear as streaks or droplets on the image, and their size, shape, and motion can be indicative of their presence. Techniques such as edge detection, color analysis, and motion analysis can be applied to identify raindrop patterns.

For fog and haze detection, the methods are different. These conditions are characterized by a general reduction in visibility and a diffusion of light. Fog and haze detection often involve analyzing the overall scene visibility, which can be done by examining the contrast, color distribution, and depth information in the images. Algorithms that incorporate the dark channel prior, haze density estimation, and atmospheric scattering models are commonly used in this context.

Moreover, machine learning techniques, such as convolutional neural networks (CNNs), can be employed for more complex and accurate detection of adverse weather conditions. CNNs can be trained on the annotated dataset to learn the features associated with rain, fog, and haze, enabling them to make predictions about the presence and severity of these conditions in new images or video frames.

In summary, rain, fog, and haze detection techniques involve analyzing image properties, such as color, contrast, motion, and visibility, to identify the presence of adverse weather conditions. These techniques serve as the foundation for the subsequent step, which is the enhancement of these images to improve visibility.

Step 5: Image Enhancement

Once rain, fog, and haze are detected in the images or video frames, the next step is to enhance these images to improve visibility and reduce the impact of adverse weather conditions. Image enhancement techniques play a crucial role in achieving this goal.

For raindrop removal, de-raining algorithms are applied. These algorithms are designed to identify raindrop patterns and then either suppress or eliminate them from the image. Some of the common approaches include using mathematical models to estimate the raindrop size and motion, which can help in generating rain-free images. Additionally, filters can be applied to the image to attenuate the impact of raindrops on image quality.

Fog and haze removal involves dehazing techniques. These methods aim to reduce the scattering and absorption of light caused by fog and haze, resulting in a clearer image. A well-known approach for dehazing is the dark channel prior, which estimates the transmission map in the image to recover the scene's true colors and details. Atmospheric scattering models are also used to estimate the scene depth and reduce the effects of scattering.

Image enhancement techniques can be further improved by incorporating machine learning models. Deep learning architectures, such as convolutional neural networks (CNNs), can be trained to understand the complex relationships between different weather conditions and the optimal enhancement strategies. These models can adapt to the specific characteristics of each image and provide more accurate enhancement.

It's important to note that the choice of enhancement techniques may vary depending on the severity of the weather conditions and the desired level of enhancement. For example, a light drizzle might require different treatment compared to a heavy downpour. Therefore, it's crucial to have a flexible enhancement approach that can adapt to varying scenarios.

After applying enhancement techniques, the output should be evaluated using standard metrics such as Mean Square Error (MSE), Peak Signal-to-Noise Ratio (PSNR), and Structural Similarity Index (SSIM) to ensure that the visibility and image quality have indeed improved.

OpenCV

Computer vision is a process by which we can understand the images and videos how they are stored and how we can manipulate and retrieve data from them. Computer Vision is the base or mostly used for Artificial Intelligence. Computer-Vision is playing a major role in self-driving cars, robotics as well as in photo correction apps.

OpenCV is the huge open-source library for the computer vision, machine learning, and image processing and now it plays a major role in real-time operation which is very important in today's systems. By using it, one can process images and videos to identify objects, faces, or even handwriting of a human. When it integrated with various libraries, such as NumPy, python is capable of processing the

OpenCV array structure for analysis. To Identify image pattern and its various features we use vector space and perform mathematical operations on these features.

The first OpenCV version was 1.0. OpenCV is released under a BSD license and hence it's free for both **academic** and **commercial** use. It has C++, C, Python and Java interfaces and supports Windows, Linux, Mac OS, iOS and Android. When OpenCV was designed the main focus was real-time applications for computational efficiency. All things are written in optimized C/C++ to take advantage of multi-core processing.

Look at the following images.

from the above original image, lots of pieces of information that are present in the original image can be obtained. Like in the above image there are two faces available and the person(I) in the images wearing a bracelet, watch, etc so by the help of OpenCV we can get all these types of information from the original image.

It's the basic introduction to OpenCV we can continue the Applications and all the things in our upcoming articles.

Applications of OpenCV: There are lots of applications which are solved using OpenCV, some of them are listed below

- face recognition
- Automated inspection and surveillance
- number of people – count (foot traffic in a mall, etc)
- Vehicle counting on highways along with their speeds
- Interactive art installations
- Anomaly (defect) detection in the manufacturing process (the odd defective products)
- Street view image stitching
- Video/image search and retrieval
- Robot and driver-less car navigation and control
- object recognition
- Medical image analysis
- Movies – 3D structure from motion
- TV Channels advertisement recognition

OpenCV Functionality

- Image/video I/O, processing, display (core, imgproc, highgui)
- Object/feature detection (objdetect, features2d, nonfree)
- Geometry-based monocular or stereo computer vision (calib3d, stitching, videostab)
- Computational photography (photo, video, superres)
- Machine learning & clustering (ml, flann)
- CUDA acceleration (gpu)

Image-Processing

Image processing is a method to perform some operations on an image, in order to get an enhanced image and or to extract some useful information from it.

If we talk about the basic definition of image processing then "Image processing is the analysis and manipulation of a digitized image, especially in order to improve its quality".

Digital-Image : An image may be defined as a two-dimensional function f(x, y), where x and y are spatial(plane) coordinates, and the amplitude of fat any pair of coordinates (x, y) is called the intensity or grey level of the image at that point.

In another word An image is nothing more than a two-dimensional matrix (3-D in case of coloured images) which is defined by the mathematical function f(x, y) at any point is giving the pixel value at that point of an image, the pixel value describes how bright that pixel is, and what colour it should be. Image processing is basically signal processing in which input is an image and output is image or characteristics according to requirement associated with that image.

Image processing basically includes the following three steps:

- Importing the image
- Analysing and manipulating the image
- Output in which result can be altered image or report that is based on image analysis

Advantages

The proposed system for rain, fog, and haze detection and removal to avoid traffic accidents using OpenCV offers several significant advantages. Firstly, it enhances road safety by addressing a major contributing factor to accidents – reduced visibility due to adverse weather conditions. By effectively detecting and removing rain, fog, and haze from images and video streams, the system provides drivers and automated driving systems with clearer and more reliable visual information, allowing them to make timely and informed decisions. This leads to a reduction in the risk of accidents, making roads safer for everyone. Additionally, the real-time implementation of the system ensures that the benefits of enhanced visibility are available precisely when they are needed, contributing to accident prevention. Furthermore, the optimization and adaptability of the system to various environmental factors and conditions make it a robust and practical solution that can be applied in diverse settings, from urban to rural roads, day or night. The integration of traffic object detection further enhances safety by recognizing vehicles, pedestrians, and other critical elements on the road, facilitating collision avoidance and traffic management. Overall, the proposed system offers a comprehensive approach to mitigate the dangers posed by adverse weather conditions on the road, making it an invaluable tool for improving traffic safety and reducing the incidence of accidents.

4. RESULTS AND DISCUSSION

The application's primary interface, as depicted in Figure 1, serves as a central hub enabling users to seamlessly navigate through various features and functionalities. From the simplicity of user registration in Figure 2 to the security-oriented password recovery process showcased in Figure 3, the application prioritizes user convenience and data protection. Upon successful registration, users encounter the login interface (Figure 4), requiring email and password authentication, thus safeguarding access to personalized features and data.

Figure 1: Displays the home screen.

Figure 2: User Registration with email and password.

Figure 3: Entering email for forgot password.

Further enriching user experience, Figure 5 offers insights into the application's background and purpose through the "About" section, fostering transparency and engagement. The Contact Us screen (Figure 6) provides direct channels for user support and feedback, enhancing satisfaction and interaction. The Dashboard screen (Figure 7) acts as a comprehensive overview of user activities and progress within the platform, while functionalities like multimedia conversion (Figure 8) and image extraction (Figure 9) empower users with versatile tools for content manipulation and analysis.

Figure 4: Presents the User Login with address.

Figure5:Displays the About.

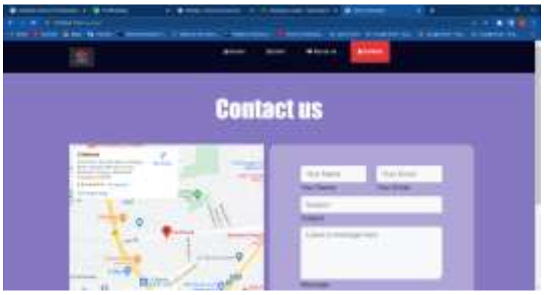

Figure 6: Displays the Contact us screen.

Figure 7: Displays the Dashboard screen.

Figure 8: Displays the upload of video or image to convert.

Figure 9: Presents the extracted image from the uploaded image.

Figure 10: Uploading profile details in My Profile.

Lastly, the "My Profile" section (Figure 10) enables users to manage personal details, customizing their experience within the application, while the password change interface (Figure 11) ensures users retain control over account security. These features collectively contribute to a user-centric platform, fostering trust and confidence in the application's capabilities and commitment to user satisfaction.

Figure 11: Change the password in the GUI screen.

5. CONCLUSION

In conclusion, the research and development of a system for rain, fog, and haze detection and removal to prevent traffic accidents using OpenCV represent a critical step towards enhancing road safety in adverse weather conditions. This comprehensive system addresses a pressing issue by combining state-of-the-art techniques in computer vision, image processing, and machine learning. By effectively detecting and removing adverse weather conditions, such as rain, fog, and haze, the system significantly improves visibility for drivers and automated driving systems, reducing the risk of accidents. The real-time implementation ensures that this enhanced visibility is provided precisely when it is needed, contributing to accident prevention. Moreover, the system's optimization and adaptability to diverse environmental conditions make it a versatile solution that can be applied in various road scenarios. The integration of traffic object detection further enhances safety by recognizing and localizing key objects on the road. The advantages of this system are clear: a reduction in accidents, enhanced safety, and an improved driving experience, ultimately making road travel safer for all. As technology continues to advance, the implementation of such systems holds the potential to save lives, reduce injury, and improve the overall safety and efficiency of our road networks.

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