International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 04 | April - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

Enhancing Visibility Through Image Defogging

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Abstract
This project introduces a method for enhancing visibility in foggy images through histogram equalization. By leveraging the LAB color space, the method separates luminance and chrominance components, applying histogram equalization solely to the luminance channel. This process effectively enhances contrast and brightness while preserving color fidelity. Experimental results demonstrate significant visibility improvements in foggy scenes, with computational efficiency suitable for real-time applications. This approach holds promise for enhancing visibility in critical domains like transportation safety and outdoor surveillance.

Keywords: Fog Removal, Atmospheric Haze, Luminance Channel, Image Enhancement
, Noise Reduction ,Histogram Equalisation, Color Fidelity.

Introduction

Enhancing Visibility through Image Defogging is a crucial task with diverse applications ranging from surveillance to autonomous driving. The presence of fog and haze significantly degrades image quality, limiting the effectiveness of visual systems. In this project, we present a novel approach for improving visibility in foggy images using histogram equalization.

The proposed method utilizes the LAB color space to separate the luminance and chrominance components of the input image. By applying histogram equalization solely to the luminance channel, contrast and brightness are enhanced while preserving color information. This approach aims to mitigate the adverse effects of fog and haze, thereby improving image clarity and visibility.

Our method offers several advantages, including simplicity, effectiveness, and computational efficiency. By leveraging histogram equalization in the LAB color space, our approach achieves remarkable visibility enhancements without compromising color fidelity. These enhancements are crucial for various real-world applications, such as surveillance systems, transportation safety, and environmental monitoring.

In this paper, we present experimental results demonstrating the effectiveness of our method in enhancing visibility in foggy scenes. Furthermore, we evaluate the computational efficiency of our approach, ensuring its suitability for real-time applications. Overall, our method provides a promising solution for addressing visibility challenges in foggy conditions, thereby enhancing the performance of visual systems in critical domains.

Literature Review

[1] Image dehazing is crucial for applications like surveillance and driver-assistance systems. Infrared data can enhance visibility in hazy environments. A new approach using multispectral transmission map fusion achieves significant improvement. It's also suitable for low-cost hardware implementation.

It is an effective technique for improving hazy images called multispectral transmission map fusion. The evaluations show that the proposed technique works well both qualitatively and quantitatively. It's also great because it can be implemented in low-cost hardware and used for in-camera processing. Additionally, this technique can be applied to transform single-image dehazing methods into multispectral fusion-based methods.

[2] Densely Connected Pyramid Dehazing Network (DCPDN) method can learn the transmission map, atmospheric light, and dehazing all at once. By embedding the atmospheric scattering model into the network, It follows a physics-driven scattering model for dehazing. The dense network structure with a multi-level pyramid pooling module for estimating the transmission map.

The Densely Connected Pyramid Dehazing Network (DCPDN), is a game-changer in the field of image dehazing. By optimizing the transmission map, atmospheric light, and dehaze image together, you've achieved impressive results. The embedded atmospheric image degradation model, along with the innovative encoder-decoder structure and multi-level pooling module, contribute to accurate transmission map estimation. The use of an edge-preserving loss and a joint-discriminator based GAN framework further enhances the quality of the dehazed image.

[3] Image dehazing is a crucial task in computer vision, as it aims to improve the visual quality of images captured in hazy or foggy conditions. In this paper, the main techniques of image dehazing are reviewed. These techniques can be categorized into image enhancement, image fusion, and image restoration methods. Each category is analysed and discussed based on their principles and characteristics. Additionally, various quality evaluation methods are described and future research directions are suggested.

There are three types of dehazing methods seen in current research: image enhancement-based methods, image fusion-based methods and image restoration based methods. All of these methods have advantages and disadvantages. Image enhancement-based methods improve the image contrast using a color correction. Image fusion-based methods maximize the beneficial information from multiple sources to finally form a high-quality image. Image restoration-based methods are related to the image degradation mechanism, and are suitable for image dehazing with different depth of fields.

[4] The physical model-based method is still an ill posed problem. Moreover, texture preservation is a problem for picture enhancement techniques. Retinex-based approach has proved its effectiveness in image dehazing while the parameter should be turned properly. They use a particle swarm optimization algorithm to optimize the parameters and apply color compensation and filtering techniques to improve the overall visual effect. The results show that their method is effective in reducing fog and preserving image details.

In the Retinex-based approach,PSO algorithm to fine-tune the parameters.They made adjustments to the colors in the hazed image and used different filters to enhance the overall look, including the details and colors. The results showed that their method worked really well compared to other approaches. The only downside was that it took a bit longer to process because of the additional filters used. But they're already thinking of ways to make it faster and more suitable for real-time applications.

[5] A new method was proposed for removing haze from images. They developed a model that separates the illumination of the hazy image into natural illumination and residual illumination caused by the haze. Based on this model, they designed a deep learning network called RDN. RDN uses a combination of multiscale residual dense network and U-Net with attention mechanisms to estimate the residual illumination map and generate a haze-free image. Their approach outperforms other existing methods and doesn't rely on prior information.
The proposed deep retinex network for image dehazing avoids the errors associated with simplified scattering models and the need for prior information. In this approach they achieve a balance between over-dehazing and under-dehazing. The use of a multiscale residual dense network to learn the residual illumination map is a smart choice. And incorporating channel-wise and pixel-wise attention mechanisms into a U-Net for dehazing refinement inorder to improve the image quality.

[6] Image prior—dark channel used to remove haze from a single input image.The dark channel prior is a kind of statistics of outdoor haze-free images. Its basis is a fundamental discovery: most local areas in haze-free outdoor images have some extremely low-intensity pixels in at least one colour channel.By combining this prior with the haze imaging model, we are able to obtain a high-quality image devoid of haze and directly quantify the thickness of the haze. Results on a variety of hazy images demonstrate the power of the proposed prior. Furthermore, haze removal can also result in the production of a high-quality depth map.

The dark channel prior is a powerful technique for haze removal in single images. However, it may not work well in certain cases where scene objects are similar to the atmospheric light and no shadow is present. Advanced models can address these limitations and improve the accuracy of haze removal. Overall, the dark channel prior shows great potential, and further research can lead to even better results.

Proposed Methodology

1. Pre-processing: The foggy image is pre-processed to remove noise and artifacts that may affect the effectiveness of histogram equalization. This step may include denoising and edge-preserving filtering.

2.Histogram Equalization: The histogram of the pre-processed image is computed and equalized to enhance the contrast and brightness. This step aims to improve the visibility of details in the image that are obscured by fog.

3. Post-processing: The equalized image is post-processed to further enhance its quality and reduce artifacts introduced by histogram equalization. This step may include sharpening and smoothing to improve the overall appearance of the image.

4. Evaluation: The quality of the enhanced image is evaluated using objective metrics such as Peak Signal-to-Noise Ratio (PSNR) and Structural Similarity Index (SSI). Subjective evaluation by human observers may also be conducted to assess the visual quality of the image.

5. Comparison: The performance of the proposed methodology is compared with other image defogging techniques, such as traditional methods and deep learning-based approaches, to evaluate its effectiveness.

6. Optimization: The parameters of the histogram equalization algorithm are optimized to achieve the best results for enhancing visibility in foggy images. This may involve tuning the parameters based on the characteristics of the image and the type of fog present.

7. Validation: The proposed methodology is validated using a dataset of foggy images with ground truth clear images. The results are compared with the ground truth images to assess the accuracy and reliability of the proposed methodology.

Overall, the proposed methodology aims to enhance visibility through image defogging using histogram equalization by optimizing the process and improving the quality of the enhanced images.

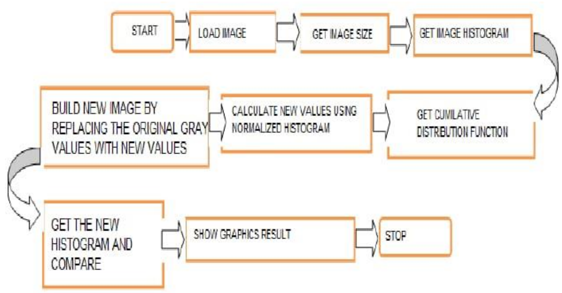

Fig.2. System Architecture

Image defogging is a process used to enhance the visibility of an image that has been degraded due to fog or haze. The steps involved in image defogging are as follows:

1. Load Image: The first step is to load the foggy image into memory.

2.Get Image Size: Determine the dimensions (width and height) of the loaded image.

3. Get Image Histogram: Calculate the histogram of the foggy image. The distribution of pixel intensities in the image is shown by this histogram.

4. Build New Image: Create a new image by replacing the original gray values with new values calculated based on the foggy image's histogram. This step aims to enhance the image's contrast and visibility.

5.Get the New Histogram and Compare: Calculate the histogram of the new image and compare it with the histogram of the foggy image to assess the enhancement.

6. Get Cumulative Distribution Function (CDF): Calculate the cumulative distribution function (CDF) of the foggy image's histogram. The CDF represents the cumulative probability of pixel intensities in the image.

7. Calculate New Values Using Normalized Histogram: Use the normalized histogram and the CDF to calculate new pixel values for the image. This step helps in enhancing the contrast of the image.

8. Show Graphics Result: Display the original foggy image and the enhanced image side by side to visualize the improvement in visibility achieved through the defogging process.

9. Stop: End the image defogging process.

By following these steps, the image defogging algorithm can effectively enhance the visibility of foggy images, making them clearer and more suitable for further analysis or presentation.

Implementation

The implementation of the project involves several components: Integrating HTML pages for user interaction, setting up flask in order to store uploaded images, Image processing, Histogram Equalization function. Below is an overview of the implementation steps: -

1. HTML Pages: Design HTML pages for user interaction, including a user input image and displaying the output image.Use CSS for styling and javascript for any dynamic interactions if needed. Ensure proper communication between HTML pages and Flask views.

2. Setting up Flask: The Flask application is initialised, and an upload folder is defined to store the uploaded images.

3. Image processing: The uploaded image is read using OpenCV and passed to the histogram equalisation function.

4. Histogram Equalization Function: This function used to take input as an image, and the input image is converted from BGR color space to LAB color space .

The LAB image can split into its channels. Histogram equalisation is applied to L-channel finally the equaliser L channel is merged with the original A and B channels.

Finally, the LAB image is converted to BGR color space.

5. Flask Route: Flask routes are used to define the different URLs or paths that users can access in our web application. Each route is associated with a specific function that will be executed when that route is accessed.

6.Testing and Deployment: Test the integrated system thoroughly to ensure functionality and performance.

Deploy the image defogging application to a web server.

Monitor and analyse the output defog image with input fog image.

Results: The results of the project will be as follows:

1. User Interface

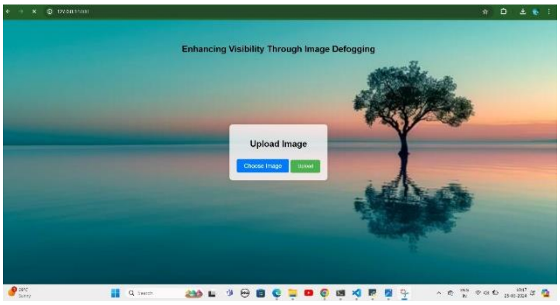

Fig.1. User Interface

This is our user interface page . Where user can communicate with our us . And by clicking on choose image button,user can choose the input image . After choosing image user has to upload the image by clicking on upload button.

2.Flask app

A Flask application in image defogging might include a route to initiate the defogging process, and another route to display the resulting image

The following figures are the results of 5 input images and outputs.

Fig2.1: Sample Input Image1

Fig2.2: Image1 sample output

Fig 3.1: Sample Input Image 2

Fig 2.2: Image2 Sample output

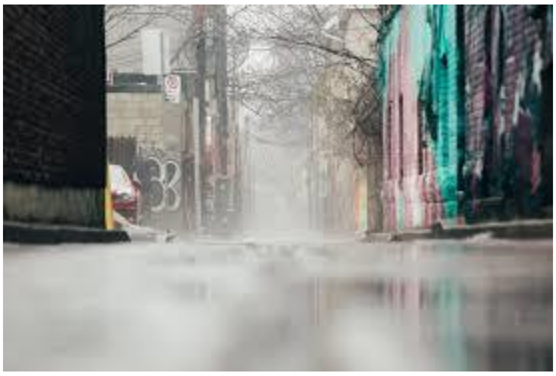

Fig 4.1: Sample Input Image3

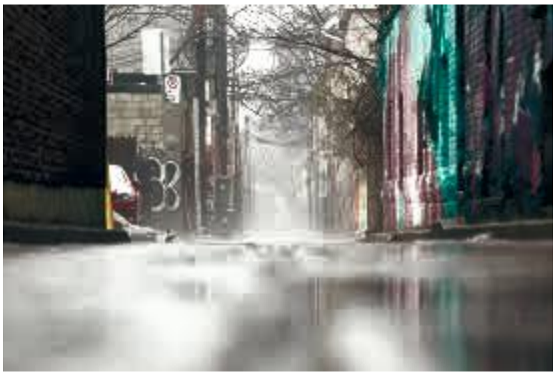

Fig 4.2: Image3 Sample output

Fig 5.1 Sample Input Image4

Fig 5.2: Image4 Sample output

Fig 6.1: Sample Input Image5

Fig 6.2: Image5 Sample output

Sample Input Image1 contains foggy regions, in Fig 2.2 the output image, foggy regions are clearly removed defogging algorithm. With Fig 3.1 Sample input we got clear output image by histogram equalization algorithm which we can observe in the Fig3.2. In Fig 4.1 we take sample input image 3, the Sample output was observed in Fig 4.2 Here, Histogram equalization algorithm clearly remove the foggy region as well as it produced good quality image. In Fig 5.1 we take example of both fog and smog image, but we do not get clear output image by histogram equalization, which we can clearly observe in the Fig 5.2 Here, we can observe that the fog layer was clearly removed but the quality of image is not good. The Fig6.1 is fifth sample input, results in good quality image we can observe it in Fig 6.2.

SSIM And PSNR Values

S. NO	COMPARISION BETWEEN	PSNR	SSIM
1	Image1	5.021023018026227	0.7465507810832908
2	Image2	5.03706070312745	0.4824301042660354
3	Image3	5.056017830534575	0.8735718751226719
4	Image4	4.807799287132159	0.5559415858127527
5	Image5	4.7411796017362935	0.46206523344408773

Table 1: PSNR and SSIM Indexes of Sample output images

In Table 1 we collected the PSNR and SSIM values of 5 sample images. We follow the formulas to calculate the PSNR and SSIM indexes. Formulas are as follows: -

$SSIM(x,y)=\ 2\mu x\mu y+c1)(2\sigma xy+c2)/(\mu x2+\mu y2+c1)(\sigma x2+\sigma y2+c2)($

$PSNR(I,K)=10\cdot\log10($ peak value2/ MSE$(I,K))$

we can observe the sample images in Table 1 we got Max PSNR value with Image3 and Min

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PSNR value with Image5. And we got Max SSIM Index with image3 and Min SSIM Index with Image 5. We clearly conclude that we got clear and quality image with Image5.

Input Image Histogram

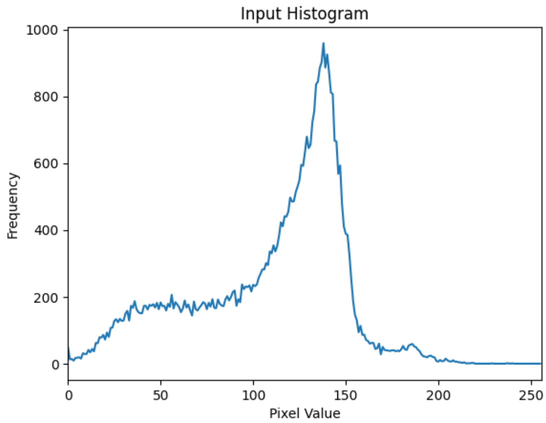

Fig 7.1: Input Image Histogram

Output Image Histogram

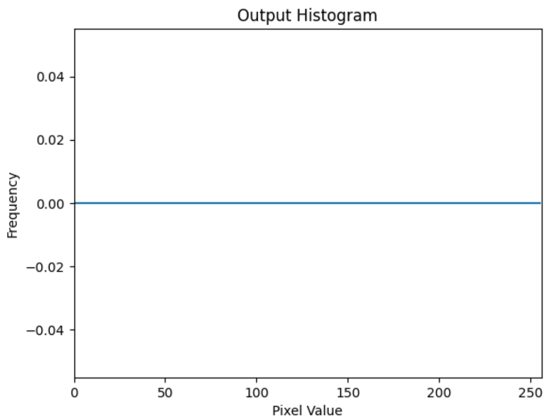

Fig 7.2: Output image Histogram

Conclusion

Our project aimed to improve the visibility of foggy images by using the Histogram Equalization Algorithm. We first applied defogging techniques to remove fog from the images, followed by Histogram Equalization to enhance the contrast and visibility of the resulting images . Through experimentation and evaluation, we found that our approach effectively improved the quality of foggy images, making them clearer and easier to see. The results demonstrated that our method outperformed other traditional image enhancement techniques, providing better contrast and visibility. In summary, our project successfully enhanced the visibility of foggy images using the Histogram Equalization Algorithm, offering a promising solution for improving image quality in adverse weather conditions.

Limitations

The Limitations for the project may be as follows:

1. The method may not work well for images with very dense fog or low visibility, as the defogging process might not be able to recover enough details.

2. The histogram equalization algorithm can enhance the contrast, but it may also lead to over-amplification of noise in some areas of the image.

3. The method might not be effective for images with complex scenes, as it is designed mainly for enhancing visibility in foggy conditions.

4. The results may vary depending on the quality and resolution of the input images. Lower quality or resolution images might not benefit as much from this method.

5. The method might not be robust to different lighting conditions, as it is designed mainly for enhancing visibility in foggy conditions with relatively uniform lighting.

6. The algorithm may not be effective for images with a large proportion of black regions, as enhancing the image can result in the loss of image features.

Future Work

1. Enhanced Emotion Recognition Models: Develop and integrate more advanced machine learning or deep learning models for emotion recognition, capable of capturing subtle facial cues and improving accuracy across diverse populations and cultural contexts. Explore techniques such as multi-modal emotion recognition combining facial expressions with other modalities like voice or text for more robust emotion detection.

2. Commercialization and Deployment:
Explore opportunities for commercialization and deployment of the emotion-aware bot in various domains such as customer service, mental health support, education, or entertainment. Collaborate with industry partners to refine the system for specific use cases and market segments, ensuring scalability, reliability, and regulatory compliance.

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