Infrared Image Enhancement Using Nearest Neighborhood Contrast Pixel Matching

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Abstract— **The infrared images are low contrast images and due to the imaging environment, the details in the image may appear fuzzy. So, in order to address this problem and also to provide images which is noise-free has been proposed an infrared image enhancement technique dependent on nearest neighborhood contrast pixel matching. In which the original image is pre-processed by filtering the noise in the image. Secondly, the edge information is extracted without being lost by fractional edge detection. Saliency weight mapping is done to avoid the loss of sensitive pixels. Then, by applying the algorithm, initial pixel contrast mapping is done. Finally, the image is reconstructed to obtain the enhanced image. The analysis has higher average value of peak signal-to-noise ratio compared to other approaches. Moreover, the enhanced results show that the images have been enhanced with higher quality and noise-free indicating our method achieves better performance than other methods.**

Keywords- ***Image Enhancement, Low contrast image enhancement, Nearest Neighbourhood pixel matching, Contrast mapping.***

I. Introduction

Generally, image processing is the process of extracting the necessary details from an image with less details to examine. The main applications of infrared imagery are target detection in military, marine recovery, detection of faulty circuit connection, space research and many more. The capture of such images may not be clear and the texture details may be fuzzy because the infrared radiation may get affected by thermal radiation in the atmosphere when the target and the sensors are far away from each other. So, image enhancement becomes a need, to get an image which is clear and the texture informations are not fuzzy.

The proposed method has an infrared image enhancement technique that addresses the challenge of unclear and fuzzy details in infrared images. Our method is based on a nearest neighborhood contrast pixel matching algorithm. In this technique, an image with lowest clarity is enhanced to a higher quality image with better resolution. Many approaches for infrared image enhancement has been developed which includes deep convolutional neural network method [1], adaptive histogram equalization [2], plateau histogram [3], adaptive histogram partition and brightness correction [4], saliency map fusion [5], etc. But, our proposed algorithm has a different approach which is, nearest neighborhood contrast pixel matching algorithm where each pixels are padded and then the average of the nearest neighbourhood pixels are taken and replaced with the central contrast pixel, in order to enhance the infrared image.

In our proposed algorithm, the flow of the process is as follows. The first step is pre-processed from the input image and fractional edge detection [6] is done to remove unwanted details and noise from the image. Then, pattern analysis takes place followed by initial contrast mapping and saliency mapping [7] are done to avoid the loss of sensitive pixels. After that, the main process, nearest neighborhood pixel matching technique is done to the present output image followed by contrast mapping. The enhanced output image is then reconstructed, so that the final output image will not lose any necessary details. The peak-signal-to-noise ratio (PSNR), mean squared error (MSE) and root mean squared error (RMSE) are measured to understand the efficiency of the output image. Comparing to other methods, our proposed method is considered to be the best at infrared image enhancement.

II. Related Work

The most straightforward and visually appealing aspect of all digital image processing methods is image enhancement. The main objective of image enhancement is to bring out elements that are concealed in an image or to increase contrast in low-contrast images. Every time a picture is transformed from one form to another, like when it is digitalized, there is some kind of output degradation. In order to process images, contrast is a crucial component. The most straightforward and visually appealing aspect of all digital image processing methods is image enhancement. The basic goal of image enhancement is to reveal hidden details in an image or to boost low contrast images' contrast. Every time an image is changed from one format to another.

Examples of the initial infrared images and their enhanced impacts in various settings are provided. The pictures are of poor quality, with muddled details and little contrast, which lessens the image's visual impact and affects viewers' ability to identify and comprehend the target. The infrared pictures that our technique improved are displayed in Figures 1 and 2.

Figure 1. Original image
Figure 2. Enhanced image

The enhanced infrared (IR) images exhibit notable improvements such as increased contrast, enhanced texture details, and improved visual effects, resulting in a more comfortable viewing experience. Thus, image enhancement has attracted more and more attention from researchers [1]–[5].

An important method for improving the clarity of the pictures in a system is image enhancement. The primary goals of image enhancement are to improve contrast in low contrast images and to reveal details that are hidden in the picture. Using the histogram equalisation method, it is possible to significantly increase the brightness and contrast of poor-quality IR pictures.

Using bi-interval histogram equalisation with details, Haoxizng Luet al.[2] focused on improving the contrast of infrared images by using multi-scale convolution to enhance the image details, taking the maximum intra-class variance and the minimum inter-class variance as the fitness function and solving it by genetic algorithm.

Chen, Feiran, Jianlin Zhang, and others [8] proposed a novel approach for showing high-dynamic-range infrared images on conventional display apparatus with adequate contrast and distinguishing detail information.

1. To maintain the weak global characteristics in different sections of the image, the original normalised image is translated into numerous brightness levels using an adaptive gamma transformation method.
2. Using the multiscale guided filter, the images in the various brightness sections are split into a base layer and detail layers independently. The nuances of each photograph are enhanced individually.
3. The enhanced pictures are combined in each brightness level to create an image with all of the world features of the original image.

Image fusion using the laplacian pyramid and wavelet transform technique is the centre of Mukane, Shailendrakumar, and Ghodake et al[9] .'s study. The primary driver behind the suggestion of this approach is recent developments in the area of image fusion techniques. MSE, NAE, and PSNR are used to gauge the performance of the picture fusion method.

Asamoah et al. [10] concentrate on three contrast enhancement techniques for image enhancement, namely Histogram Equalization (HE), Adaptive Histogram Equalization (AHE), and Contrast Limited Adaptive Histogram Equalization (CLAHE). These techniques are then compared using the eight (8) quality image measurement metrics.

B ACHAR, Swathi, M S, Sannidhan, and BHANDARI, Abhir have conducted a comparative analysis of quality measures for a number of image improvement approaches, including contrast modifications, histogram equalization, adaptive histogram equalization, and unsharp masking [11]. The results are then contrasted with different metrics for measuring image quality, including the peak signal-to-noise ratio (PSNR), mean squared error (MSE), and structural similarity index (SSIM).

According to Lal, S., and Chandra, M. [12], a useful algorithm that has two major phases is displayed for enhancing the contrast of natural images. 1) The sigmoid function is modified to analyse the low-quality picture. 2. Using the CLAHE (Contrast Limited Adaptive Histogram Equalization) technique, pictures acquired from the result of the previous step are once more handled to improve contrast.

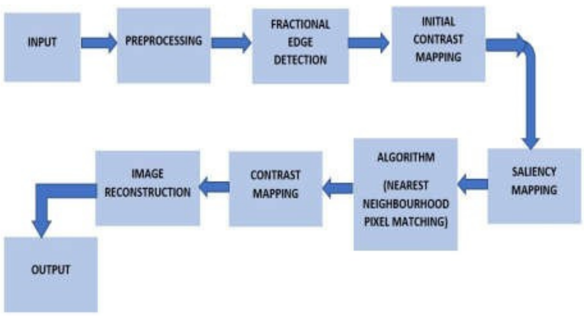
Based on the observation of HE, Stark, J. A. et al.[13] suggested AHE (Adaptive Histogram Equalization), a novel method for enhancing image contrast. Here, a vital component known as the cumulation function was utilised to construct a grey-level mapping of the image from the HE.

A review of different techniques for evaluating image clarity was given by Ruikar, J. D., et al. in their article [14]. Along with the initial picture, a different database was made that contained twelve variations of the same image. Eleven picture quality measures were applied to the aforementioned database, resulting in an estimated image quality score.

III. Proposed System

Image enhancement is a method for enhancing images that involves modifying digital images so that the results are better suited for exhibition or additional image analysis. Consequently, it is a crucial pre-processing stage that is employed in vision systems and numerous picture processing apps. The primary goal of image enhancement is to make changes to images that make the visual material easier for humans or machines to recognize. The figure in this paper's structure for the suggested picture enhancement technique. The primary goal of this research is to use the closest neighborhood pixel matching method to produce a drawing of higher quality, and to assess the enhanced sketches' improved sketch quality metrics. The block diagram for the proposed system is shown below in the figure 3

We divided this method into several blocks. Firstly, the edges of the image are detected because those pixels are very important pixels for further processing but to prevent this edge



information Laplacian operator is used. Secondly, initial contrast mapping is done to the pre-processing block where nearest neighborhood contrast pixel matching algorithm is applied. Then, sensitive pixels of the input image are calculated by using filter and finally, final contrast mapping is applied to the infrared image where nearest neighborhood contrast pixel matching algorithm is applied.

Figure 3. Block Diagram

A. Pre-processing

The primary goal of pre-processing is to raise the image's quality so that it may be examined more thoroughly. Pre-processing allows for the suppression of undesirable distortions and the enhancement of features required for a certain application. Here, Median filter is used which is used to remove noise and to preserve the edge information of the input image. By using median filter, we are separating noise from the image which is displayed as a noise co-efficient data and the filtered data is shown separately. The output of the pre-processing block is shown in the figure below.

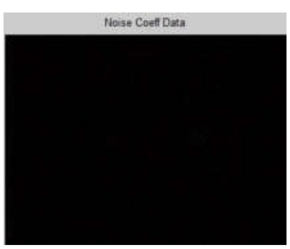


Figure 3. Noise Co-efficient data ***Figure 4. Filtered data***

B. Edge Detection

The concept of edge detection is used to detect the presence and location of edges by varying the intensity of an image. In image processing, various operations are used to detect edges. It can detect variations in grey levels, but it responds quickly when noise is detected. Edge detection is a critical task in image processing. Edge detection is the main technique used in scene analysis, picture segmentation, and pattern identification. The edge points of a picture are extracted using this filter. An picture undergoes sudden alterations when the edge contours across the brightness of the image. To retrieve the boundary information from an input image by taking initial pixel weight map and 2D kernel matrix is convoluted with the input image. The output of the fractional edge detection block is shown in the figure 5 below.

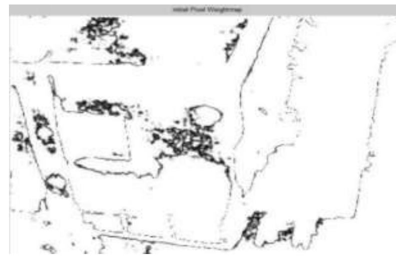


Figure 5. Fractional edge detection

C. Nearest Neighbourhood contrast Pixel Matching Algorithm

In this block, each pixel of the image are padded individually and then, the weighted average of the nearest neighborhood pixels is taken which is replaced with the central pixel of the pixel which is padded within the nearest neighborhood of the considered pixel.

D. Contrast Mapping and Saliency Mapping

Contrast mapping may be a strategy utilized in picture handling to map one set of gray levels within the picture to modern values through gray-level transformation. Saliency mapping may be a way to measure the spatial backbone of a particular lesson in each picture. A saliency outline is built by utilizing the slopes of the yield of an image over the input. Here, initial contrast mapping, saliency mapping and final contrast mapping are done to extract the smooth image passing through several levels of mapping technique which are shown in the below figure 6, figure 7 and figure 8.

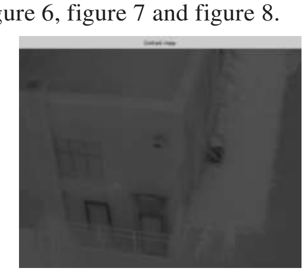


Figure 6. Initial contrast mapping

Figure 7. Saliency mapping ***Figure 8. Final contrast mapping***

E. Image Reconstruction

In the image reconstruction block, the edge details and necessary information that are extracted previously are convoluted with the processed image to get a lossless enhanced image with high clarity and better resolution. Image reconstruction is simply known as resolution enhancement because the processed image lacks necessary details such as edge information which are added to it before producing the final enhanced output image. The image reconstruction part is very important because without this process the final output image would be vague and incomplete.

F. Final Enhanced Output Image

Figure 9. Final Enhanced Output Image

The final enhanced image shown below, clearly shows that there is no noise in the image and the clarity of the image has improved highly with better resolution. The fuzzy details present in the original image has been removed where the edge details are extracted in the pre-processing block and the image is processed throughout the other blocks. Then, the necessary details with edge information are convoluted and the final enhanced output image is produced. The final enhanced image is shown is below figure 9.

IV. QUANTITATIVE ANALYSIS

PSNR	58.5981
MSE	0.0897
RMSE	0.2996

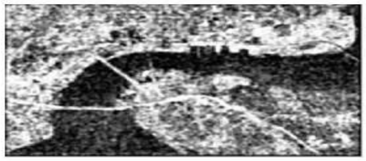
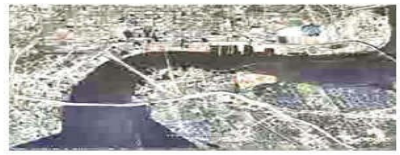
The performance of this algorithm is measured by quantitative metrics such as PSNR, MSE and RMSE which are used to compare with other algorithms. Quantitative analysis for above original and enhanced images is tabulated below.

Table 1. Performance parameters for proposed method

A. Comparison with other algorithm

In this study, we conducted enhancement experiments on three distinct scenes to evaluate the effectiveness of our approach. For all three scenes the original images and the enhanced images of both our algorithm (NNCPM) and existing algorithm (ABHE) were compared and analyzed. In below tables the comparison of ABHE algorithm with NNPCM algorithm on all three images are shown along with their respective PSNR, MSE, and RMSE values.

Table 2. Comparison of ABHE with NNCPM algorithm

	Adaptive Bi-Interval Histogram Equalization	Nearest Neighbourhood Contrast Pixel Matching
Original Image		
Enhanced Image		
PSNR	57.7324	62.2985
MSE	0.1104	0.0383
RMSE	0.3323	0.1957

From table 2., The original infrared image is characterized by low brightness, poor visual quality, and insufficient prominence of detail features. However, by employing the NNCPM algorithm, the image undergoes enhancement, resulting in significantly improved quality compared to the ADHE method. The disadvantage of ADHE is it will too brighten the original image but that not the case in NNCPM algorithm. The higher the PSNR, the better the quality of the compressed, or reproduced, picture. The condition to decide the PSNR's esteem is given in Equation 1. The PSNR value 68.7579 which is higher than the existing shows that our method has better performance. The lower the value of MSE and RMSE, the lower the error. The equation to determine MSE and RMSE value is given in equation 2 and equation 3. In above table, the MSE and RMSE values of our method is very low which shows that the image enhanced is noise-free.

From table 3., we can see that the image enhanced by ADHE have overexposure and the edges are blurred resulting in image blurring. Meanwhile, the image enhanced by NNCPM algorithm has higher quality compared to ADHE and the blur has been removed. Our method makes the image smoother by enhancing the fuzzy details. The PSNR value 60.6731 which is higher than the existing shows that our method has better performance. In addition, the MSE and RMSE values of our method is very low which shows that the image enhanced is noise-free indicating it has better performance.

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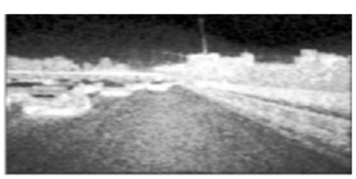
Table 3. Comparison of ABHE with NNCPM algorithm

	Adaptive Bi-Interval Histogram Equalization	Nearest Neighbourhood Contrast Pixel Matching
Original Image		
Enhanced Image		
PSNR	57.7087	60.6731
MSE	0.1110	0.055689
RMSE	0.3332	0.235985

Table 4. Comparison of ABHE with NNCPM algorithm

	Adaptive Bi-Interval Histogram Equalization	Nearest Neighbourhood Contrast Pixel Matching
Original Image		
Enhanced Image		
PSNR	57.7263	68.7579
MSE	0.1106	0.0086
RMSE	0.3326	0.0930

In above table 4, ready to see that the picture upgraded by the ADH calculation isn't self-evident, and the brightness is still dim, demonstrating that the picture quality is still low. On the other hand, the image enhanced by our method NNCPM is prominent, clear and the details are processed with brightness and high quality. The PSNR value 62.2985 which is higher than the existing shows that our method has better performance. In addition, the MSE and RMSE values of our method which are very low or nearly zero which shows the image has less error than other.

V. . CONCLUSION

The proposed method has a novel infrared image enhancement technique, that is, the nearest neighbourhood contrast pixel matching algorithm. In this technique, an image with lowest clarity is enhanced to a higher quality image with better resolution. Many approaches for infrared image enhancement have been developed, but our proposed algorithm has a different approach in which each pixelis padded and then the average of the nearest neighbourhood pixels is taken and replaced with the central contrast pixel, in order to enhance the infrared image. The input image is first pre-processed and fractional edge detection is done to remove unwanted details and noise from the image. Then, pattern analysis takes place followed by initial contrast mapping and saliency mapping are done to avoid the loss of sensitive pixels. After that, the main process, nearest neighbourhood pixel matching technique is done to the present output image followed by contrast mapping. The enhanced output image is then reconstructed, so that the final output image will not lose any necessary details. The peak-signal-to-noise ratio (PSNR), mean squared error (MSE) and root mean squared error (RMSE) are measured to understand the efficiency of the output image. The proposed algorithm enhances the infrared image which is usually affected by thermal radiation in the atmosphere and provides a high-resolution output image which helps in understanding the details in the image better. Comparing to other infrared image enhancement techniques, our proposed algorithm is considered to be the best with better time complexity. Our future work will focus on improving this technique to overcome the drawbacks involving scenes in which the light is too dim or too bright.

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