A

SEMINAR REPORT

ON

IMAGE ENHANCEMENT UNDER IMAGE PROCESSING

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CERTIFICATE

This is to certify that the seminar entitled "Image Enhancement Under Image Processing" submitted by Mr. Aryan Akshyadeep (2022UEE1335) at Malaviya National Institute of Technology Jaipur towards partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Electrical Engineering at Department of Electrical Engineering has been carried out by him under my supervision.

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This satisfaction that I feel at the successful completion of my seminar would be incomplete if I did not mention the names of people, whose noble gesture, affection, guidance, gratitude and respect to all those who inspired me in the completion of my seminar, all the expertise in this seminar belongs to those listed below. I express my sincere gratitude to Head of the Department Prof. HARPAL TIWARI, Seminar Coordinator Dr. PRERNA JAIN and my respected guide Dr. HEMANT KUMAR MEENA for their noble gesture, support and guidance given to me in completing this seminar. I also thank all the teaching and non-technical staff of our department for giving their kind cooperation during the development of my seminar. Additionally, I extend my appreciation to my peers and fellow participants for their contributions, discussions, and collaboration during the seminar sessions. The exchange of ideas and perspectives has been invaluable in enhancing my learning experience.

ARYAN AKSHYADEEP

ABSTRACT

Image enhancement is a critical aspect of image processing, aiming to improve the quality and interpretability of images for various applications ranging from medical imaging to surveillance and satellite imagery. This research project delves into the advancements in image enhancement techniques facilitated by image processing methodologies. The study evaluates and compares different image enhancement algorithms, considering their effectiveness in enhancing image quality while preserving important image features and details. The project explores traditional methods such as histogram equalization and spatial domain filtering, alongside more contemporary techniques including wavelet transforms, neural networks, and deep learning-based approaches. Emphasis is placed on the adaptability of these techniques across different types of images and scenarios, including low-light conditions, noise reduction, and contrast enhancement. Moreover, the research investigates the integration of subjective and objective evaluation metrics to assess the perceptual quality and quantitative fidelity of enhanced images. By comprehensively analysing the strengths and limitations of various image enhancement algorithms, this study aims to contribute to the development of more robust and versatile image processing techniques for real-world applications.

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1. INTRODUCTION

In today's digital age, images have become an indispensable medium for communication, information sharing, and artistic expression. However, the quality of images captured by various devices or generated through digital means often suffers from imperfections such as noise, blurriness, low contrast, and other distortions. This degradation can significantly impede the effectiveness and aesthetic appeal of images, hindering their utility in diverse fields ranging from medical imaging and remote sensing to multimedia applications and entertainment.

Image enhancement, a fundamental task in the realm of image processing, aims to improve the visual quality of images by mitigating or eliminating these imperfections. Through the application of sophisticated algorithms and techniques, image enhancement endeavours to restore details, enhance contrast, reduce noise, and sharpen edges, thereby producing images that are clearer, more vibrant, and visually appealing.

The pursuit of image enhancement techniques has garnered significant attention from researchers, engineers, and practitioners across various domains. Its importance is underscored by its wide-ranging applications, including medical diagnosis, satellite imaging, surveillance, forensic analysis, and consumer photography. Moreover, with the proliferation of social media platforms, online content creation, and digital marketing, the demand for high-quality images has intensified, further emphasizing the need for robust image enhancement solutions.

The field of image enhancement encompasses a diverse array of methodologies, ranging from traditional techniques such as histogram equalization and filtering to more advanced approaches leveraging machine learning, deep learning, and artificial intelligence. These methodologies often involve a delicate balance between improving image quality while preserving important features and details.

In this research project, we delve into the realm of image enhancement under image processing, exploring various techniques, algorithms, and methodologies aimed at enhancing the visual quality of images. Through empirical analysis, experimentation, and evaluation, we seek to contribute to the advancement of image enhancement techniques, addressing challenges, identifying opportunities, and offering insights that pave the way for more effective and efficient image enhancement solutions in diverse real-world applications.

1.1 Objectives of the Seminar Report:

1) Understanding the different types of image degradations that necessitate enhancement.
2) Studying various image enhancement techniques in both spatial and frequency domains.
3) Implementing common image enhancement algorithms using image processing software or libraries.
4) Evaluating the effectiveness of different enhancement techniques on various image types.
5) Gaining practical experience in enhancing images for improved visual quality and information extraction.

2. LITERATURE REVIEW

Image enhancement is a crucial aspect of image processing, aimed at improving the visual appearance of images for various applications. Several techniques have been proposed in the literature to enhance images, addressing challenges such as noise reduction, contrast enhancement, and sharpening.

One widely employed method is histogram equalization (HE). HE redistributes pixel intensities to achieve a uniform histogram, thereby enhancing the contrast of the image. Despite its effectiveness, HE may lead to over-enhancement and unnatural appearance in some cases [1].

To address the limitations of HE, adaptive histogram equalization (AHE) techniques have been introduced. AHE modifies the histogram of small image regions individually, thus avoiding over-enhancement while improving local contrast. However, traditional AHE methods may suffer from amplification of noise in homogeneous regions [2].

To mitigate the shortcomings of traditional AHE, various modified AHE techniques have been proposed. Contrast-limited adaptive histogram equalization (CLAHE) limits the contrast amplification in local regions, preventing over-enhancement and reducing noise amplification [3]. Another promising approach is the use of spatial domain methods such as image smoothing and sharpening filters. These techniques aim to reduce noise and enhance edges, thereby improving image quality [4]. Furthermore, recent advancements in deep learning have led to the development of neural network-based image enhancement methods. Convolutional neural networks (CNNs) have shown promising results in enhancing images by learning complex mappings between low-quality and high-quality images [5].

In summary, image enhancement techniques play a vital role in image processing, with methods ranging from traditional histogram-based approaches to modern deep learning-based methods. Future research may focus on integrating different enhancement techniques and developing more efficient algorithms for specific applications.

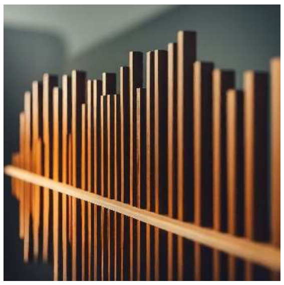
3. METHODOLOGY

In this section, we outline the methodologies employed in image enhancement. It includes a step-by-step explanation of different techniques such as:

1. **Histogram Equalization**:

- Histogram equalization is a technique in image processing that improves image contrast by manipulating the intensity distribution of pixels.

- In low-contrast images, the pixels cluster around a narrow range of intensities. Histogram equalization stretches this distribution, using the entire intensity range more evenly.



- This process enhances contrast, making details in the image more visible.

Benefits of Histogram Equalization

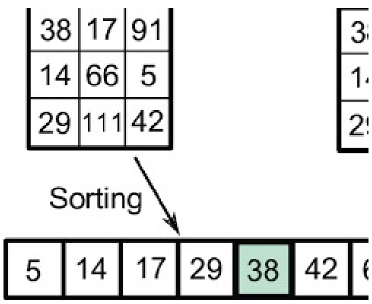
- Improves visual quality, especially in low-contrast images.
- Makes details more prominent.
- Broadens the apparent dynamic range of the image.

Things to Consider

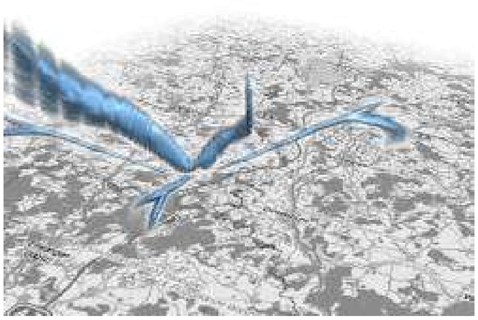
- Can introduce noise in some cases.
- May affect colour balance if applied to colour images (convert to grayscale first).

2. **Spatial Domain Enhancement**:
   - Spatial domain enhancement techniques modify image pixels directly to improve visual quality.
   - Filtering and masking are two common methods for local contrast enhancement.

Filtering: A small mask (filter) slides across the image. Pixel values within the mask are averaged (mean filter) or manipulated (e.g., median filter) to create a new intensity value for the centre pixel. This can sharpen edges or reduce noise depending on the filter type.

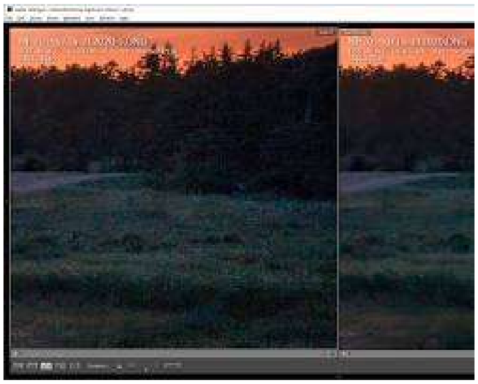


Masking: Here, a separate mask defines the region of interest. The image is filtered only within this mask, enhancing contrast in specific areas while preserving details elsewhere. Unsharp masking is a popular example where a blurred version of the image is subtracted from the original, highlighting sharpened edges.



3. **Frequency Domain Enhancement**:

   Frequency domain enhancement utilizes the Fourier transform to manipulate an image's frequency components for targeted manipulation. Images in the spatial domain (normal view) are converted to the frequency domain, where information is represented by frequency and intensity.



Here, we can selectively filter frequencies to achieve various enhancements:

- **High-Pass Filtering (Sharpening):** Boosts high frequencies, sharpening edges and details.

- **Low-Pass Filtering (Smoothing):** Suppresses high frequencies, reducing noise and blurring details.

4. **Contrast Stretching**:

   Improves image details by expanding the range of pixel intensities. Here's a breakdown of linear and non-linear method:

Linear Stretching

- Uniformly expands intensity values across the image.
- Simpler to implement but can create unwanted clipping (loss of details) in highlights or shadows.

Non-linear Stretching (e.g. Histogram Equalization)

- Analyses the distribution of pixel intensities (histogram).
- Spreads out the intensities for better contrast, often leading to more natural-looking enhancements.

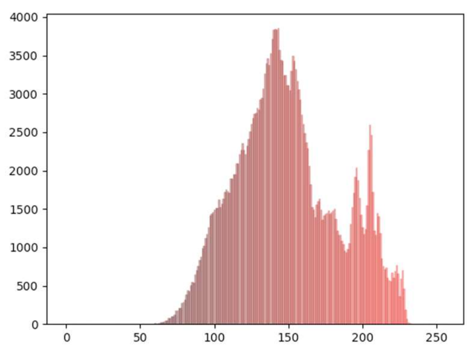
3.1 **Implementation of the mentioned methodologies:**

The image shown below, is the original image:

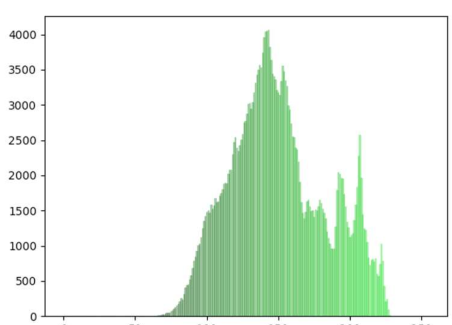
[6]

Now the following graphs determine the Histogram of the above the mentioned image, defining the intensity of the image.

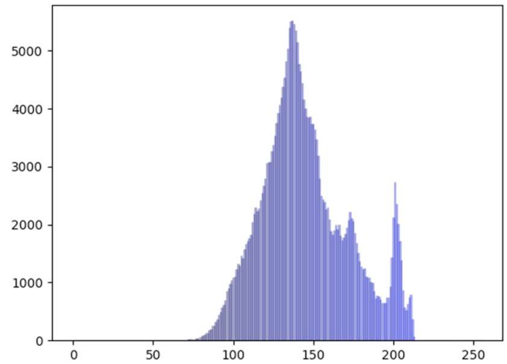
Red Band of the Image:



Green Band of the Image:



Blue Band of the Image:



Now based on the above data, the input values are considered and the following Python is code is written, thus Python is one of the methods of implementation for image enhancements.

The python code [7] is as follows:

```
# Method to process the red band of the image
def normalizeRed(intensity):
    iI      = intensity

    minI    = 86
    maxI    = 230

    minO    = 0
    maxO    = 255

    iO      = (iI-minI)*(((maxO-minO)/(maxI-minI))+minO)
    return iO

# Method to process the green band of the image
def normalizeGreen(intensity):
    iI      = intensity

    minI    = 90
    maxI    = 225

    minO    = 0
    maxO    = 255
```

```
    iO      = (iI-minI)*(((maxO-minO)/(maxI-minI))+minO)
    return iO

# Method to process the blue band of the image
def normalizeBlue(intensity):
    iI      = intensity

    minI    = 100
    maxI    = 210

    minO    = 0
    maxO    = 255

    iO      = (iI-minI)*(((maxO-minO)/(maxI-minI))+minO)
    return iO


# Create an image object
imageObject     = Image.open("./glare4.jpg")

# Split the red, green and blue bands from the Image
multiBands      = imageObject.split()

# Apply point operations that does contrast stretching on each color band
normalizedRedBand      = multiBands[0].point(normalizeRed)
normalizedGreenBand    = multiBands[1].point(normalizeGreen)
normalizedBlueBand     = multiBands[2].point(normalizeBlue)

# Create a new image from the contrast stretched red, green and blue brands
normalizedImage = Image.merge("RGB", (normalizedRedBand,
normalizedGreenBand, normalizedBlueBand))

# Display the image before contrast stretching
imageObject.show()

# Display the image after contrast stretching
```

```
normalizedImage.show()
```

After the execution of the above the program in the Python software, the below picture is the result.

4. EVALUATION METRICS

Now in the world of image enhancements, evaluation of algorithms and techniques is crucial for determining their effectiveness in improving image quality. Here are the major parameters under which the evaluation parameters are majorly considered:

a) Peak Signal-to-Noise Ratio (PSNR)
b) Structural Similarity Index (SSIM)
c) Mean Squared Error (MSE)
d) Visual Inspection

a) Peak Signal-to-Noise Ratio (PSNR):

- It is termed as the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation.
- PSNR is usually expressed as a logarithmic quantity using the decibel scale.
- Higher PSNR values indicate better image quality, with the peak value often being 100 dB.

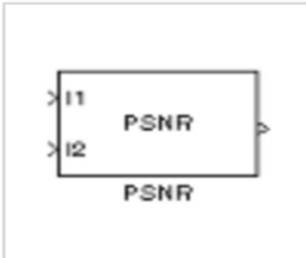
Now to compute the PSNR of an image [8], the block first calculates the mean-squared error using the following equation:

$$MSE = \frac{\sum_{M,N} [I_1(m,n) - I_2(m,n)]^2}{M * N}$$

In the previous equation, M and N are the number of rows and columns in the input images. Then the block computes the PSNR using the following equation:

$$PSNR = 10 \log_{10}\left(\frac{R^2}{MSE}\right)$$

In the previous equation, R is the maximum fluctuation in the input image data type.



Libraries:
Computer Vision Toolbox / Statistics

The mentioned metric, PSNR, can be also found as a block in the software MATLAB under the simulink category, thus making it easier for us to evaluate the required data in the software itself.

b) Structural Similarity Index (SSIM):

- SSIM evaluates the perceived quality of an image by comparing its structural information, luminance, and contrast against a reference image.
- It computes similarities in terms of luminance, contrast, and structure, providing a measure of how close the enhanced image is to the ground truth.

The SSIM formula [9] is based on three comparison measurements between the samples of *x* and *y*: luminance (*l*), contrast (*c*) and structure (*s*). The individual comparison functions are as follows:

$$l(x,y) = \frac{2\mu_x\mu_y + c_1}{\mu_x^2 + \mu_y^2 + c_1}$$

$$c(x,y) = \frac{2\sigma_x\sigma_y + c_2}{\sigma_x^2 + \sigma_y^2 + c_2}$$

$$s(x,y) = \frac{\sigma_{xy} + c_3}{\sigma_x\sigma_y + c_3}$$

The variables are also mentioned as follows:

μ_x the pixel sample mean of x;

μ_y the pixel sample mean of y;

σ_x^2 the variance of x;

σ_y^2 the variance of y;

σ_{xy} the covariance of x and y;

The resultant SSIM index is a decimal value between -1 and 1, where 1 indicates perfect similarity, 0 indicates no similarity, and -1 indicates perfect anti-correlation.

Now, mentioning a few syntaxes [10] that are used to find the SSIM value in the MATLAB software:

Syntax:

```
ssimval = ssim(A,ref)
ssimval = ssim(A,ref,Name,Value)
[ssimval,ssimmap] = ssim(__)
```

Description:

`ssimval = ssim(A,ref)` calculates the structural similarity (SSIM) index for grayscale image or volume A using ref as the reference image or volume. A value closer to 1 indicates better image quality.

`ssimval = ssim(A,ref,Name,Value)` calculates the SSIM, using name-value pairs to control aspects of the computation.

`[ssimval,ssimmap] = ssim(__)` also returns the local SSIM value for each pixel or voxel in A.

c) **Mean Squared Error (MSE):**

- MSE calculates the average squared differences between pixel values in the original and enhanced images.
- Lower MSE values imply less distortion and better image fidelity.
- It does not necessarily correlate with human perception of image quality.

The mean-squared error using the following equation:

$$MSE = \frac{\sum_{M,N} [I_1(m,n) - I_2(m,n)]^2}{M * N}$$

In the above equation, M and N are the number of rows and columns in the input images.

Now, mentioning a few syntaxes [11] that are used to find the MSE value in the MATLAB software:

Syntax:

`err = immse(X,Y)`

Description:

`err = immse(X,Y)` calculates the mean-squared error (MSE) between the arrays X and Y. A lower MSE value indicates greater similarity between X and Y.

d) Visual Inspection (Subjective Evaluation):

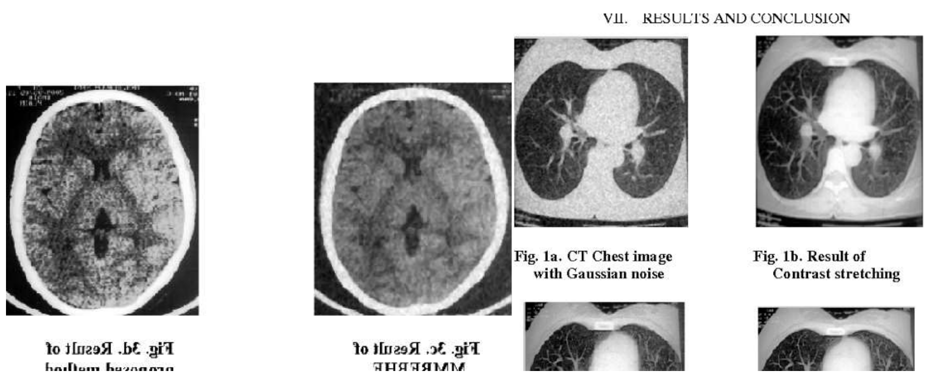
- Despite the effectiveness of quantitative metrics, visual inspection remains invaluable.
- Human perception often detects nuances and artifacts that numerical measures might miss.
- Experts assess the enhanced images subjectively, considering factors like sharpness, clarity, colour accuracy, and naturalness.
- Visual inspection provides qualitative feedback on the perceptual quality of the enhanced images, complementing quantitative metrics.

5. APPLICATIONS OF IMAGE ENHANCEMENTS

Image enhancement plays a crucial role in various fields by improving the visual quality of images, making it easier to extract information, and enabling further processing tasks. Now mentioning the applications of image enhancements by also highlighting the problem that they can address:

a) Medical Imaging:

- **Problem:** Medical images like X-rays, MRIs, and ultrasounds may have low contrast, noise, or artifacts that hinder diagnosis.
- **Enhancement Techniques:**
  - **Contrast stretching:** Improves the visibility of subtle details by expanding the range of pixel intensities.
  - **Noise reduction:** Removes unwanted grain or artifacts that can obscure crucial information.
  - **Edge detection:** Sharpens edges to highlight boundaries of organs, tumours, or fractures.

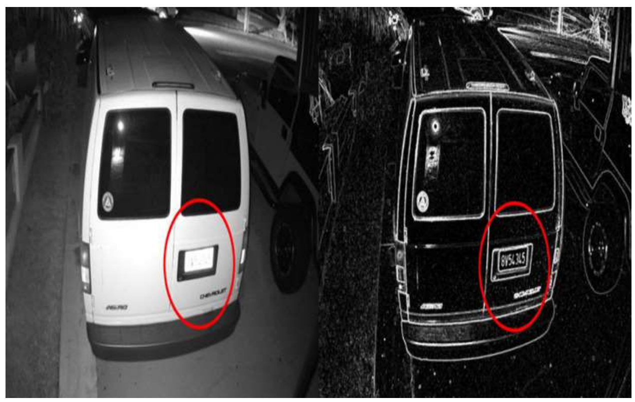


[12]

- **Benefits after image enhancements:**
  - Enables earlier and more accurate diagnosis.
  - Improves treatment planning and monitoring.
  - Reduces the need for additional imaging procedures.

b) **<u>Surveillance</u>:**

- **Problem:** Security cameras often capture images with poor lighting, low resolution, or motion blur.
- **Enhancement techniques:**
  - **Brightness/Contrast Adjustment:** Improves visibility in low-light conditions.
  - **Sharpening:** Enhances details like facial features or license plates.
  - **Deblurring:** Reduces motion blur to improve clarity of moving objects.

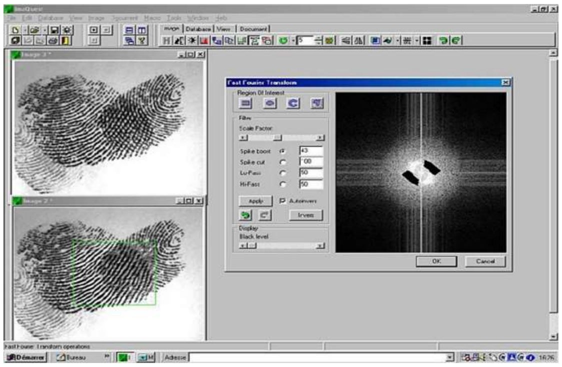


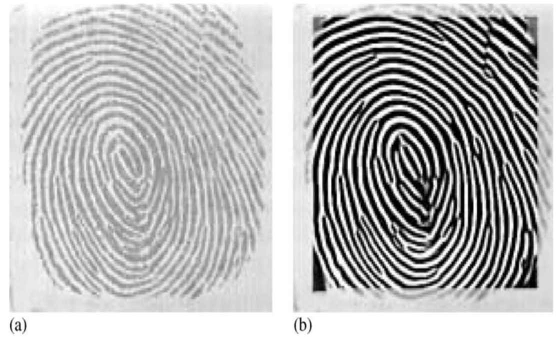
[13]

- **Benefits after image enhancements:** Enhanced surveillance footage helps security personnel identify suspicious activity and track down criminals.

c) **<u>Forensic</u>:**

- **Problem**: Evidence photos from crime scenes may be blurry, have poor lighting, or contain unwanted details.
- **Enhancement techniques:**
  - **Sharpening:** Clarifies fingerprints, tire tracks, or other crucial markings.
  - **Colour correction:** Improves color accuracy for better identification of objects.
  - **Noise reduction:** Removes artifacts or distortions that might obscure details.



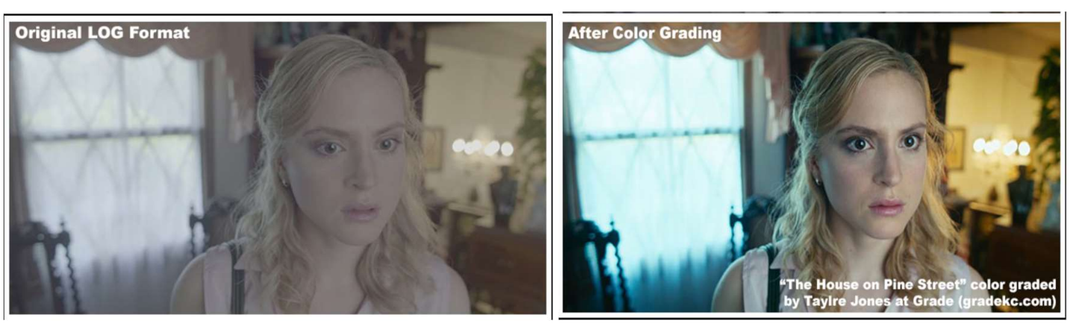


Fingerprint image: (a) before and (b) after enhancement.

[14] [15]

d) <u>Movies</u>:

- **Problem:** Movies may require colour correction, noise reduction, or special effects that alter the image.
- **Enhancement techniques:**
  - **Colour grading:** Creates a specific mood or atmosphere by adjusting colour palettes.
  - **High Dynamic Range (HDR) enhancement**: Expands the range of colours and brightness for a more realistic look.
  - **Special effects:** Introduces visual modifications for fantastical scenes or visual effects.



[16]

- **Benefits after image enhancements:**
  - Image enhancements in movies enhance the visual experience for audiences, creating a more immersive and engaging atmosphere.

6. CHALLENGES AND FUTURE DECISIONS

6.1 Challenges faced in the image enhancement sector:

a) **Noise Reduction**: One of the primary challenges in image enhancement is reducing noise while preserving important image details. Noise can arise from various sources such as sensor limitations, transmission errors, or environmental factors.

b) **Artifact Removal**: Image enhancement techniques often introduce artifacts such as halos, blurring, or ringing effects. Balancing the removal of artifacts without compromising image quality is a significant challenge.

c) **Dynamic Range Adjustment**: Enhancing images with a wide dynamic range requires careful adjustment to ensure both shadow and highlight details are preserved. Techniques like tone mapping in high dynamic range (HDR) imaging face challenges in maintaining natural appearance while enhancing details.

d) **Color Accuracy**: Achieving accurate color representation is crucial in image enhancement, especially in applications like medical imaging or satellite imagery analysis. Challenges include color balance, consistency across different devices, and handling color distortions.

e) **Computational Complexity**: Many advanced image enhancement algorithms are computationally intensive, requiring significant processing power and memory resources. Balancing computational complexity with real-time performance is a challenge, particularly for applications in embedded systems or mobile devices.

6.2 Future decisions to be made in the image enhancement sector:

a) **Integration of AI and Machine Learning**: Leveraging AI and machine learning techniques, such as deep learning, can significantly improve the effectiveness of image enhancement algorithms. Future research should explore neural network architectures tailored specifically for image enhancement tasks.

b) **Adaptive Algorithms**: Future image enhancement algorithms are likely to be adaptive, dynamically adjusting parameters based on image content and user preferences. Adaptive approaches can improve robustness and performance across diverse image types and applications.

c) **Cross-Modal Enhancement**: Extending enhancement techniques beyond traditional 2D images to other modalities such as depth maps, infrared images, and multispectral data opens up new possibilities for various applications, including medical imaging, remote sensing, and augmented reality.

d) **Real-time Processing**: With the increasing demand for real-time image enhancement in applications like video streaming, surveillance, and autonomous vehicles, future research should focus on developing efficient algorithms optimized for high-speed processing.

e) **Ethical Considerations**: With the increasing use of image enhancement in fields like forensic analysis, surveillance, and entertainment, ethical considerations regarding privacy, authenticity, and bias become paramount. Future decisions may involve developing guidelines and standards to ensure responsible use of image enhancement technologies.

7. CONCLUSION

In conclusion, the realm of image enhancement within image processing offers a multitude of techniques and methodologies aimed at improving the visual quality of images for various applications. Through our exploration, we have delved into several key aspects and advancements in this field.

Firstly, we have examined the importance of image enhancement in numerous domains, including medical imaging, satellite imagery analysis, surveillance systems, and multimedia content processing. The ability to enhance images not only enhances visual aesthetics but also plays a crucial role in aiding decision-making processes across diverse industries.

Secondly, our investigation has highlighted various techniques employed in image enhancement, ranging from basic methods like histogram equalization and spatial domain filtering to more advanced algorithms such as wavelet transform and deep learning-based approaches. Each technique offers unique advantages and trade-offs, and the selection of the most suitable method depends on factors such as the nature of the image, desired enhancements, computational resources, and application requirements.

Moreover, the evolution of image enhancement techniques has been greatly influenced by technological advancements, particularly in the fields of computer vision, machine learning, and artificial intelligence. The integration of these technologies has facilitated the development of more sophisticated and automated enhancement algorithms capable of addressing complex image quality issues effectively.

In conclusion, image enhancement remains a dynamic and evolving area of research within image processing, with far-reaching implications for numerous applications. By continuing to innovate and refine enhancement techniques, researchers can unlock new possibilities for improving image quality, enabling advancements in fields such as healthcare, remote sensing, security, and entertainment. As we look towards the future, the pursuit of enhancing visual perception through image processing techniques will undoubtedly continue to play a pivotal role in advancing technological capabilities and enriching human experiences.

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[13] Picture Courtesy: HitPaw Video Enhancer; License plate, text, or logo is hard to read.
https://www.hitpaw.com/video-tips/cctv-video-enhancement.html

[14] Picture Courtesy: Horiba Scientific; Imaquest Fingerprint Software, Enhancement and Comparison Follow up Training

https://www.horiba.com/twn/scientific/products/spex-forensics/training/imaquest-fingerprint-software-enhancement-and-comparison-follow-up-training/

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