MBEYA USNIVERSITY OF SCIENCE AND TECHNOLOGY

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Digital Image Processing: Importance, Applications & Techniques.

Digital image processing (DIP) is the use of a digital computer to process digital images through an algorithm. As a subcategory or field of digital signal processing, digital image processing has many advantages over analog image processing. It allows a much wider range of algorithms to be applied to the input data and can avoid problems such as the build-up of noise and distortion during processing.

Digital image processing is important for various reasons:

i. Digital image processing improves the quality of images by reducing noise, enhancing contrast, and sharpening details, making them more visually appealing and informative.
ii. It enables the extraction of useful information from images, facilitating tasks like object detection, recognition, and tracking, essential in fields such as surveillance, medical imaging, and autonomous vehicles.
iii. Through compression, digital image processing reduces the storage space required for images while preserving essential information, enabling efficient transmission and storage of large amounts of visual data.
iv. Digital image processing helps in recovering degraded or damaged images by removing artifacts, restoring lost details, and reconstructing missing parts, vital in historical document preservation and forensic analysis.
v. It aids in the diagnosis and treatment of medical conditions by providing accurate and detailed images for analysis, assisting doctors in making informed decisions and improving patient outcomes.
vi. Digital image processing also plays a crucial role in remote sensing applications, such as satellite imagery analysis, environmental monitoring, and natural disaster management, providing valuable insights for decision-making and resource management.

Applications of Image Processing:

I. Medical Imaging:

Image processing has been extensively used in medical research and has enabled more efficient and accurate treatment plans. Example, Image-guided surgery, and research using techniques like MRI, CT scans, and X-rays.

II. Traffic Sensing Technologies:

Digital image processing has also enabled the development of the Video Image Processing System or VIPS. This consists of an image capturing system, a telecommunication system and an image processing system. When capturing video, a VIPS has several detection zones which

output an “on” signal whenever a vehicle enters the zone, and then output an “off” signal whenever the vehicle exits the detection zone. These detection zones can be set up for multiple lanes and can be used to sense the traffic in a particular station. Besides this, it can auto record the license plate of the vehicle, distinguish the type of vehicle, monitor the speed of the driver on the highway and lots more.

III. Face Detection

Face detection is a vital tool used in security, biometrics and even filters available on most social media apps these days. It follows deep learning algorithms where the machine is trained with the specific features of human faces, such as the shape of the face, the distance between the eyes etc.

IV. Image Reconstruction

Image processing can be used to recover and fill in the missing or corrupt parts of an image. This involves using image processing systems that have been trained extensively with existing photo datasets to create newer versions of old and damaged photos.

V. Entertainment:

Image and video editing, special effects in movies, and video games.

VI. Automotive Industry:

Autonomous driving, lane detection, and obstacle avoidance.

VII. Character Recognition

Character recognition, usually known as optical character recognition or abbreviated as OCR. It is mechanical or electronic translation of images of either handwritten or printed text (usually captured by a scanner) into machine editable text. It is a wide area for researchers in pattern recognition, artificial intelligence and machine vision. For many document input tasks, character recognition is the most cost effective and speedy method available.

IMAGE ENHANCEMENT

Image enhancement is basically improving the interpretability or perception of information in images for human viewers and providing `better' input for other automated image processing techniques. There exist various techniques that can enhance a digital image which include, but not limited to:

i. Point Processing:

This technique adjusts the pixel values individually. Examples include contrast stretching, histogram equalization, and intensity transformations like gamma correction.

ii. Neighborhood Processing:

It considers the relationship between a pixel and its neighboring pixels. Common methods include smoothing (e.g., averaging, Gaussian filtering) and sharpening (e.g., Laplacian sharpening, unsharp masking).

iii. Histogram Processing:

This involves manipulating the histogram of the image to enhance its appearance. Histogram equalization is a popular method where the histogram of the image is modified to achieve a uniform distribution of pixel intensities.

iv. Spatial Filtering:

Spatial filters modify pixel values based on their spatial coordinates. Techniques include low-pass filtering (to reduce noise), high-pass filtering (to enhance edges), and median filtering (to remove salt-and-pepper noise).

v. Edge Enhancement:

These techniques aim to enhance edges in an image. Common methods include Sobel operator, Prewitt operator, and Roberts cross operator.

IMAGE RESTORATION

The concerns of the image restoration are the removal or reduction of degradations which are included during the acquisition of images e.g.; Noise, pixel value errors, out of focus blurring or camera motion blurring using prior knowledge of the degradation phenomenon. This means it deals with the modelling of the degradation and applying the process (inverse) to reconstruct the image.

Restoration techniques:

i. Median Filter

This is the statistical method as implied by the name .In this method pixel value is replaced by the median of the pixels in the neighborhood found .The usage is to remove the salt and pepper noise .It is used widely and can reduce the noise in the images excellently. This filtering removes the noise but keeps the edges. This tends to overcome the image to become blur and that is its advantage over the smoothing model.

	10	5	20				
	14	80	11				
	8	3	22				

3, 5,8.10,11,14,20,22,80

Median (central value 18 is replaced by 11)

ii. Adaptive Filter

In adaptive filter behavior changes based on statistical characteristics of image inside the filter region. It is that type of linear filter which has a transfer function controlled by a variable parameter. For removal of impulse noise in images these filters use the color and gray space in comparison to

other filters .It has best noise suppression results, preserve edges in better way and hence yield better quality.

iii. Linear Filters

In this, we replace each pixel by the linear combination of its neighbors. The operations that are implemented include sharpening, smoothing and edge enhancement. This type of filter has its implementation in salt and pepper noise and Gaussian noise.

iv. IBD (Iterative Blind De-convolution) method.

This technique was given by Ayers and Dainty (1988).It is a method of blind de-convolution. In this method Fourier transform is calculated which causes less computation. In this method image recovery is done by (little or no) prior knowledge of PSF (Response of an imaging system to a point source or point object (point spread function)). It results in high resolution and Quality. The drawback of this method is that convergence is not guaranteed.

v. Non Negative and Support Constraints Recursive Inverse Filtering (NAS-RIF)

This filtering technique was put forward by D. Kunde. The aim is to reconstruct a reliable estimated image from a blurred image. In this algorithm estimation of the target image is made. Error function is minimized to make the estimate which contains the domains of image. The advantage is that we only need to find support domain of target area and need to be cautious such that the estimation obtained will be positive.

vi. Wiener Filter

Wiener filter includes both the degradation function and statistical characteristics of noise into the restoration process. The main objective of the method is to find an estimated value of the uncorrupted image value such that the mean square value between them is minimized. The drawback of inverse and pseudo inverse filtering is that they are noise sensitive. But Wiener filtering is not noise sensitive so this is the advantage of the Wiener filtering. Its response is better in presence of noise.

vii. Lucy- Richardson Algorithm Techniques

The image restoration is divided into blind and non-blind de convolution. In non-blind PSF is known. The Richardson–Lucy is the most popular technique in the field of astronomy and medical imaging .The reason of popularity is its ability to produce reconstructed images of good quality in the presence of high noise level. Lucy and Richardson found this in the early 1970's from byes theorem. Lucy Richardson is nonlinear iterative method. This method is gaining more acceptance than linear methods as better results are obtained here. The inverse Fourier transform of Optical Transfer Function (OTF) in the frequency domain is the PSF, where OTF gives linear, position-invariant system the response to an impulse. The Fourier transfer of the point (PSF) is OTF.

<u>Applications of restoration:</u>

i. In the area of astronomical applications characterized by Poisson noise, Gaussian noise; image restoration has played a very important role in the area of imaging.

ii. SR technique is also useful in medical imaging such as Computerized Tomography (CT) and Magnetic Resonance Imaging (MRI). While the resolution quality is limited the acquisition of multiple images is possible. This can help the surgeon to operate more successfully over the exact part of the body with care.
iii. Over the multispectral bands of satellite imagery, multispectral image restoration can be carried out in order to improve the resolution of the captured satellite images.
iv. In order to improve the video resolution, the motion blur estimation can be performed in the real time video image processing applications.
v. To enhance the HR of the mobile camera.

Conclusion:

Restoration of images is a difficult problem to resolve. The main objective of this work is to carry out a comparative study. Though every technique has got its own way of dealing with the problem and have their own pros and cons. It is concluded from the above explanations that usage of the techniques is governed by the understanding, requirement and the standard of the output needed.