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RESEARCH ARTICLE

A REVIEW ON DIGITAL IMAGE PROCESSING: APPLICATIONS, TECHNIQUES AND APPROACHES IN VARIOUS FIELDS

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Abstract

Image processing is a complex process that involves various techniques and algorithms. There is no fixed pattern and hence there are limits on adopting the image processing in any process. Present work is a thorough review of the different applications of image processing technique in various fields of modern engineering. Digital image processing (DIP) is being used in various applications such as video modification, biometric systems in offices, endoscopy, quality monitoring in textile and other production industries, digital photograph enhancing, signature verification etc. It also gives thorough insight of various techniques involved in the image processing such as image acquisition, image segmentation, image transformation, image restoration, image compression etc. The advantages and limitations of certain strategies and algorithms used in image processing such as SIFT, SURF, BRIEF and ORB are discussed in detail.

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Introduction:-

There are two types of image processing viz. Analog image processing (AIP) and digital image processing (DIP). AIP can be used for the hard copies like printouts and photographs. Image analysts use a range of fundamentals of interpretation while using these visual techniques. In DIP, computer algorithms are used to perform image processing. Digital image processing is preferred over the AIP.

Numbers of algorithms are available to be used with the input data.

Problems such as noise or distortion in signal are avoided. Fast, efficient and versatile DIP has become indispensable part of modern engineering and preferred over AIP [1].

The image processing emphasizes on the target area to be studied as well as the knowledge of analyst. Association is another important tool in image processing through visual techniques. Hence during the analysis, one has to apply personal knowledge and collateral data to image processing. Image processing is closely related with the artificial vision or simulated vision hence it has at least one of the probable goals.

1. Hallucination Means monitoring and describing the object which do not exist in practice but their features are described
2. Image restoration and/or sharpening in order to improve the quality of image i.e. contrast, brightness, tint, hue, sharpness etc.

3. Image reposition Here we search for the image of interest. The parameters of desired image such as shape, colours, pattern etc. are mentioned and we seek the desired image from provided images
4. Measurement of pattern This is done to measure the range of objects in a given image or targeted area
5. Image acknowledgement This is a process of differentiating specific objects in the image [2].

As there are no fixed techniques for all applications, we need to study all possible techniques their advantages and disadvantages. Each technique has its own advantages and limitations. The review provides discussion about various applications is given. The review provides thorough knowledge of various techniques adopted in image processing preferably DIP. Finally, the review discusses few algorithms commonly used in image matching.

Applications of image processing:

There are several applications of image processing as mentioned below

Image sharpening and restoration:

It is the process of enhancing the visual impact of the image so as to improve the information content. This involves sharpening of edges/ boundaries, and/ or contrasting. Many algorithms for accomplishing contrast enhancement have been developed and applied to problems in image processing. Few are mentioned below

1. Contrast enhancement
2. Intensity, hue, and saturation transformations
3. Density slicing
4. Edge enhancement
5. Making digital mosaics
6. Producing synthetic stereo images
7. Noise removal using a Wiener filter
8. Linear contrast adjustment
9. Median filtering
10. Unsharp mask filtering

Character recognition:

Processing speed of scanned images can be improved by character recognition. It identifies and extracts the text content from different data fields. For example, when we scan a form and use document imaging software to process it, OCR (Optical Character Recognition) allows us to transfer information directly from the document to an electronic database. OCR converts scanned or photo images of typewritten or printed text into binary data. It is a technique of digitizing printed manuscripts such that following processes such as editing, search, text to speech conversion, key data extraction and text mining can be done. In previous stages, these automations were performed with images of every character. This limited the use of fonts to only one at a time. Modern era of today has provided great versatility on size, type and orientation of various fonts. Some marketable methods are capable of duplicating formatted output that very much look like the original scanned pane including columns, images and other non-textual components [3].

Target recognition:

Automatic Target Detection/Recognition (ATDR) detects, classify and track the target objects embedded in an image produced by laser radar (LR), synthetic- aperture radar (SAR), or an infrared or video camera. ATDR converts the signal from the sensor into a digital image then separate the target from background or surrounding area by extracting a coarse shape or outline of the target object.

Finally, it identifies the object by matching the features describing the target object [4]. Segmentation is one of the main steps in image analysis for detection, and recognition or identification of objects. Several techniques and algorithms have been developed for image segmentation process like (i) Edge Detection Methods, (ii) Region splitting and (iii) Region Growing Methods, (iv) Clustering Methods. Many algorithms and techniques are utilized in ATR process, but no satisfactory single approach has yet been found. We can make a high performance ATR system by blending several approaches together.

Pattern recognition:

In this type the objects or images are identified by matching them with different patterns provided. The matching is done on the basis of similarities in shape, colour etc. Best example is the 'finding Woldo problem'.

Biometric identification:

Biometrics refers to metrics related to the characteristics of human beings, such as fingerprints, hand geometry, signatures, retina and iris patterns, voice waves, DNA etc.

New and emerging biometric techniques are:

1. Human scent recognition
2. EEG biometrics
3. Skin spectroscopy
4. Knuckles texture
5. Finger nails recognition [5].

The comparative analysis of different biometric techniques is mentioned in table 1. Most popular among the biometric recognition is fingerprint identification. Every individual has unique fingerprints. Most fingerprint matching systems are based on four types of fingerprint representation schemes: gray scale image, phase image, skeleton image, and minutiae. Due to its distinctiveness, compactness, and compatibility with features used by human fingerprint experts, minutiae-based representation has become the most widely adopted fingerprint representation scheme [6].

Table 1:- Comparison of different biometric techniques.

Biometrics	Facial Recognition	Iris scan	Finger print	Finger vein	Voice Recognition	Lips recognition
Accuracy	Low	High	Medium	High	Low	Medium
Cost	High	High	Low	Medium	Medium	Medium
Size of template	Large	Small	Small	medium	Small	Small
Long term stability	Low	Medium	Low	High	Low	Medium
Security level	Low	medium	Low	High	Low	High

Feature Extractor:

Feature extraction is the core of fingerprint technology. The quality of captured image is enhanced by removing the noise using noise reduction algorithm which processes the image and determines minutiae. Most frequently used minutiae in applications are points of bifurcation and ridge endings.

Matcher:

The fingerprint images are matched to those in the database for either identification or matching i.e. one-to-many matching or one-to-one matching.

There are some other applications such as remote sensing, transmission encoding, machine vision, colour processing, video processing and microscopy.

Techniques of image processing:

Figure 1 represents different techniques of image processing.

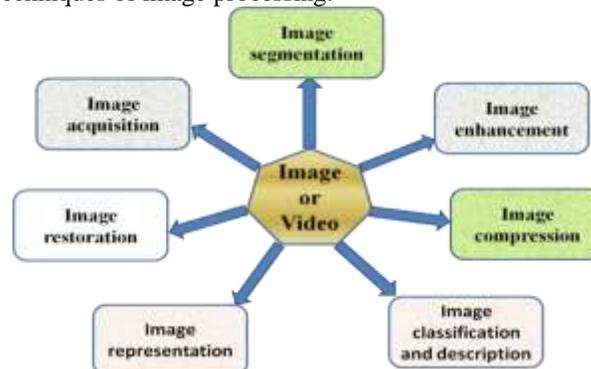


Figure 1:- Techniques of Image Processing.

Detail explanation is given below.

Image Segmentation:

Segmentation is a process of dividing the image into component regions or objects; in order to help in annotation of the object scene. Image segmentation is done to identify the content of the image carefully. In this context, edge detection is a fundamental tool for image segmentation. Several general-purpose algorithms and techniques are adopted for image segmentation. Despite of availability of several methods of segmentation, selection of method and hence the algorithm relies on the nature and type of image. Thus the selection of method of segmentation and the appropriate algorithm remains a challenge image processing and computer vision [5].

Depending on the approaches, the segmentation may be either region based, edge Based, threshold or feature based clustering.

Region based segmentation:

Process of dividing an image into regions (small groups of connected pixels having similar properties). Regions are used to interpret images. A region may correspond to particular object or different parts of an object. Region-based techniques are generally better in noisy images where borders are difficult to detect. Fair accuracy levels are offered in region based methods.

Edge based segmentation:

It focuses on the discontinuous intensity values and similar intensity values. In case of discontinuous intensity values, the partition of image based on abrupt changes in intensity, such as edges or boundaries. Edge detection is the problem of primary value in image analysis. The obtained boundary marks are edges of the desired object. Hence by the detection of its edges, the object can be segmented from the image. The output that is received by applying edge detection algorithm is a binary image. Edge based methods are interactive in nature.

There are three fundamental steps in edge detection:

1. Filtering & Enhancement: In order to facilitate the detection of edges, it is essential to repress as much noise as possible and determine changes in intensity in the neighbourhood of a point, without destroying the true edges.
2. Detection of edge points: Determine which edge pixels should be discarded as noise and which should be retained (usually, thresholding provides the criterion used for detection).
3. Edge localization: Not all of the points in an image are edges for a particular application. Edge localization determines the exact location of an edge. Edge thinning and linking are usually required in this step. [5]

Thresholding:

Thresholding is a simple and powerful technique for segmenting images having light objects on shady background. By choosing appropriate threshold T , it converts a multi level image into a binary image and then divide image pixels into several regions and separate objects from background. Depending on T , there are two approaches viz. Local thresholding (when T is constant) and global thresholding (T have multiple values) [7]. If the background illumination is uneven then the global thresholding fails. If the intensity of any pixel (x, y) is greater than or equal to the threshold value, then it is considered as a part of the object otherwise it belongs to background. Resistance to noise is less when we adopt this method.

Feature Based segmentation:

Clustering is the process of grouping together of objects based on properties so that each cluster contains similar objects which are dissimilar to the objects of other clusters. Clustering is performed by different algorithms using various methods for computing or finding the cluster. The quality of the good clustering methods produces high intra-cluster and low inter-cluster similarities. A general approach to image clustering emphasises on following issues:

1. How to represent the image?
2. How to organize the data?
3. How to classify an image to a certain cluster?

The Clustering methods are classified into 2 types.

K mean clustering:

K-mean is one of the fast, robust, simplest unsupervised learning algorithms that solve the well known clustering problem. The method is to classify the given data set through a certain number of k clusters that are fixed a priori. K-mean clustering algorithms gives optimal result when data set are dissimilar.

Fuzzy C-Mean [FCM] Algorithm etc:

Fuzzy Clustering is a method which allows the objects to belong to more than one cluster with different membership. This is the one of the effective method for pattern recognition. Most commonly used fuzzy clustering algorithms is the Fuzzy C-Mean [8]. By using FCM we can retain information of the data set. In FCM, the data point is assigned membership to each cluster center as a result of which data point may belong to more than one cluster center. However, the evils of digital image segmentation still put some great challenges for computer vision. Many researchers had created several methods to deal with the problem of image segmentation. Zimmer et al. [9] created an active contour (snakes) method to detect the mobility of live cells. Coskun et al. [10] used the inverse modelling to detect the mobility of living cells. Mukherjee et al. [11] applied thresholding to handle the tracking problem. Researchers are preparing several image segmentation algorithms for the segmentation process as per requirements.

Model based segmentation:

This technique is based on Markov random field. For color segmentation inbuilt region constraint are used. To define accuracy of edges MRF is joined with edge detection [12]. This method contains the relations amongst color components.

Image compression:

Compression of the records of the digital images to eliminate the duplication of the data in order to store and transmit it more efficiently is called compression of image [13]. The image compression is of two types viz. lossy and lossless.

Lossless compression:

If the quality of image remains unaltered after compression, it is lossless. It is mostly used for medical imaging, technical drawing contents and for archival purposes etc

Lossy compression:

In lossy compression the quality of data decreases after compression. Lossy approaches are used in those environments in which minor loss of quality is acceptable for high speed. The common is JPEG which compresses full color or gray scale images. In which the image is divided into eight by eight blocks such that no overlapping is formed among them. JPEG use discrete cosine transforms technique for compression [14]. There is another technique for compression known as Wavelet transform. Through wavelet data is divided into different frequency components each one is studied separately. Wavelets have advantages over traditional Fourier approaches in examining physical circumstances.

Classification of image:

To extract the information from the images, label, and pixels from the images, classification is done. Many images of the same objects are required. For effective classification appropriate scheme and adequate training samples are required. Classification is done as per user's need [15]. Numerous classification approaches are accessible like as artificial neural networks, expert systems and fuzzy logic etc. Various types of classification algorithms like as per pixel, sub pixel, per field. 'Per-pixel classification' is mostly used method. 'Sub pixel algorithms' comprises of varied pixel problem, provide higher level of accuracy. For fine 3D resolution, 'data per field classification' is the best option.

The classification techniques may either be supervised or unsupervised. In supervised classification, spectral signatures which are obtained from training samples are used to classify an image. With the help of multivariate classification tools, image is classified. In unsupervised classification the output depends on machine without any interaction with the user. In this techniques pixels belong to same category are grouped into one class.

Image Restoration:

Obtaining a perfect image from corrupted and noisy image is done by a process known as image restoration [16]. Restoration rebuilds those images spoiled due to noise or system error. Degradation may be due to noise from the

sensor, camera misfocus and atmospheric disturbance. There are two types of procedures are used to restore the image. The picture whose quality is degraded via some reasons,

There are various processes involved in restoration of image.

1. Inverse filtering: In this method we look at an image assuming a known blurring function. We will see that restoration is good when noise is absent.
2. Weiner Filtering: It provides optimal trade-off between de-noising and inverse filtering. The results are better than those with straight inverse filtering.
3. Wavelet Restoration: Here three wavelet based algorithms are used to restore the image.
4. Blind De-convolution: If neither assumption nor the information about the additive noise in image is present, then blind filtering is done. These are the typical steps followed during the process [17, 18].

Image enhancement:

It increases the quality of image by applying various filters. Prior knowledge of degradation is necessary to restore the image. Restoration of the images might be achieved via two types of model viz. degradation Model and restoration model [17].

Image enhancement is done to make the image more suitable than the original one, for a specific application such as graphic display. Quantifying the criterion for enhancement is difficult task, hence various image enhancement techniques are adopted. Image enhancement is of two types depending on the approaches.

Spatial domain enhancement (SDE):

In which pixel value varies as a function of intensity of the surrounding

Frequency domain enhancement (FDE):

It may involve the point processing this involves following steps

1. Intensity transformation
2. Image negative
3. Contrast stretching
4. Grey level slicing
5. Histogram processing
6. Image subtraction
7. Image averaging [18].

Acquisition of image:

It is the first step of any visualization scheme. When the image is obtained then various processes are applied on the image. Basically, an image acquisition is a process through which images are retrieved from various resources. The most common method for image acquisition is real time acquisition. Real time acquisition creates a pool of files which are processed automatically. An image acquisition method is useful to produce 3D geometric data [19].

Image Representation:

Image representation means converting the raw data in such a way so that computer processing can apply on it. Basically, two types of techniques are used to represent the pictures.

Boundary representation:

It displays internal shape of the picture. Thus it focuses on the shape of the object, whether it is corner, rounded or any other shape.

Region representation:

It is used when the internal properties of image are to be studied. Depends upon level of processing of images via machine there are four methods of image representation such as pixel based, Block based, Region based and Hierarchical based. Image representation is suitable for the formation of entities, knowledge based models extracted from image databases that are created using predefined decision rules [20].

Image transformation:

Arithmetic operations on images or complex mathematical operations which convert images from one representation to another. Mathematical Operations include simple image arithmetic, Fourier, fast Hartley transform, Hough transform and Radon transform [21-23]. Most popular is Fourier Transform (FT).

Image matching and different approaches:

Feature detection and image matching are still the important areas to work on in machine vision and robotics. Ideal feature detection technique should be adopting with transformations such as rotation, scale, illumination, noise and affine transformations in image. Ideal features should be highly distinctive, such that a single feature to be correctly matched with high probability [23-24]. Image matching in DIP is a complex process and it uses several algorithms. Given below are 3 most popular approaches.

Scale Invariant Feature Transform (SIFT):

Lowe's SIFT solves the image rotation, affine transformations, intensity, and viewpoint change in matching features. The SIFT algorithm has 4 basic steps.

Intimation of scale space extrema using the Difference of Gaussian (DoG).

Key point localization where the key point candidates are localized and refined by eliminating the low contrast points.

Key point orientation assignment based on local image gradient and Descriptor generation to compute the local image descriptor for each key point based on image gradient magnitude and orientation. SIFT is a feature detector developed by Lowe in 2004 [25]. Although SIFT is very efficient in object recognition applications, it requires a large computational complexity which is a major drawback especially for real-time applications [25-26]. To improve the computational complexity, several variants and extensions of SIFT are developed [27-30].

Speed up Robust Feature (SURF):

SURF approximates the DoG with box filters. Squares are used instead of Gaussian averaging as the convolution with square is much faster if the integral image is used. This is used simultaneously for different scales. The SURF uses a BLOB detector which is based on the Hessian matrix to find the points of interest. For orientation assignment, it uses wavelet responses in both horizontal and vertical directions by applying adequate Gaussian weights. SURF uses the wavelet responses for feature description. A neighbourhood around the key point is selected and divided into subregions. For each subregion the wavelet responses are represented to get SURF feature descriptor. The sign of Laplacian which is already computed in the detection is used for underlying interest points. The sign of the Laplacian distinguishes bright blobs on dark backgrounds from the reverse case. In case of matching, the features are compared only if they have same type of contrast (based on sign) which allows faster matching [30]. SURF technique, which is an approximation of SIFT, performs faster than SIFT without reducing the quality of the detected points [31]. Both SIFT and SURF are thus based on a descriptor and a detector.

Binary Robust Independent Elementary Features (BRIEF):

Rublee et al. proposed Oriented FAST and Rotated BRIEF (ORB) as another efficient alternative for SIFT and SURF. It requires less complexity than SIFT with almost similar matching performance [32,33]. Any of these feature detection methods can also be employed in remote sensing application such as sea ice applications, e.g. Zehen Lieu et al. used the SIFT algorithm based matching to find the icebergs whose shapes has changed due to collision or splits [34]. Also feature tracking algorithms were used for ice motion tracking e.g. Ronald Kwok [35]. Little literature is available on comparison of SIFT and SURF [36-38] however, there are no papers on the comparison of ORB with them. Fish eye distortions are used for creating hemispherical panoramic images caused by lens of camera or manually created by using spherical distortions. Planetariums apply fish eye paper ion of night sky, flight simulations in order to create immersive environment for the trainee's uses the fish eye paper ion, some motion-picture formats also use these paper ions [39]. Meteorology uses fish eye lenses to capture cloud formation.

Oriented FAST and Rotated BRIEF ORB:

ORB is a fusion of the FAST key point detector and BRIEF descriptor with some modifications [32]. Initially to determine the key points, it uses FAST. Then a Harris corner measure is applied to find top N points. FAST does not compute the orientation and is rotation variant. The intensity weighted centroid of the patch is computed from the

corner at center. The moments of the vector from this corner point to centroid gives the orientation to improve the rotation invariance. In plane rotation degrades the performance of BRIEF. In ORB, a rotation matrix is computed using the orientation of patch and then as per orientation, BRIEF descriptors are steered.

Conclusion:-

Image processing has become indispensable part of modern engineering as it is being adopted in various fields such as biometry, signature identification, image enhancing, quality control in various production industries, machine vision techniques etc. There are mainly two types of image processing viz. AIP and DIP. DIP has its own advantages. DIP has various applications such as image sharpening and restoration, character recognition, signature or pattern recognition, target recognition, image enhancing. Each application adopts a single or combination of different techniques such as image acquisition, segmentation, transformation, enhancement etc. Various algorithms are adopted for image matching and DIP such as SIFT, SURF, BRIEF and ORB etc. Thus this review describes various aspects of DIP and gives thorough insight on applications, techniques and algorithms adopted.

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