

A Comprehensive Survey of Digital Image Processing Techniques from the Perspective of Embedded Computing Environment

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Abstract— In recent trend, image processing domain plays a vital part of real time applications in modern world. Such image processing technique helps to carry process on the digitized image to provide better solutions. Varieties techniques taken together forms the set of tools for image processing application, most of which are involved in enhancing the clarity of image, making the images noise free and compressing the original image to compressed data in order to reduce the storage space. Soft-computing techniques help the realization of image processing algorithms perform better optimization in producing desired output. Survey work presented through this paper brings out a brief overview various digital image processing techniques and their applications in varieties of domains in context of the real-time image processing applications using embedded systems environment involving dedicated and special purpose hardware are discussed.

Keywords—Digital Image Processing(DIP), Image Registration (IR), Image Enhancement(IE), Image Restoration(IR), Image Compression(IC), Image Segmentation(IS), Image Recognizing(IRg), Image Smoothing(IS), Image Fusion(IF), Image Steganography(ISg), Soft-Computing Techniques (SCT), Embedded Platform(EP).

I. INTRODUCTION

Digital image processing (DIP) has found its application in varieties of fields other than the domains of engineering and technology [1] involving realization through both hardware as well as software, with a due consideration of factors such as maintaining trade-off balance between processing time and quality precision of the output image, performance improvement like execution time without scarifying accuracy. Many image processing applications demand realization of the target image processing requirements through dedicated embedded systems involving system on chip (SoC), FPGA, GPU and multicore processors (MCPs). The use of system on chip (SOC) makes the application portable and compact [2]. In many DIP applications, the efficiency of system can be improved by using 64-bit or 128-bit processor

while the speed of operation can be improved by use of higher system clock or parallel processing hardware. Thus, the DIP applications in order to get the desired output with optimum time and memory complexity need to compromise with the quality and precision of output [2].

Basically, digital image processing can be viewed as a form of signal processing in which the input will be given as an image, such as a photograph or video frame; the output of image processing will be either an image or a set of characteristics or parameters that are related to given image [3]. Image processing involves processing or altering an existing image in a desired manner and also helps in obtaining the image in the readable format. Most techniques of image-processing involve treating the image as 2-dimensional signal and applying standard signal-processing techniques to it. The MatLab and MathCAD are the two software tool environments which suits for image processing. In this, MatLab's based on matrix-oriented language and well suited for manipulating images. The resultant image produced very in clarity and economical way of expressing image processing operations.

Some benefits of image processing:

- Visualization helps in identification of the objects that are not visible.
- Image processing is faster and cost effective in embedded systems.
- Noise free.
- Image sharpening and restoration - To create a better image.
- Images can be retrieval easily from the database

Image: An image may be defined a two-dimensional function $f(x,y)$, where x and y are the coordinates for a point in a given plane; and f is the intensity or gray level function or else color depth function at the position denoted by of x and y .

Digital Image: If the value of $f(x,y)$ for all x and y are discrete and finite then the image is called digital image.

The rest of the paper is organized as follows: we present discussion on component of an image processing system in Section 2 and about various transformation techniques for image processing methods in Section 3. In Section 3, we present discussions on various image processing technique. Discussion on soft-computing techniques is discussed in Section 4. In Section 5, we have presented discussion on dedicated and special purpose hardware for digital image processing systems. Finally, in Section 6 we present concluding remarks of the work.

II. COMPONENT OF AN IMAGE PROCESSING SYSTEM

The Block diagram given below in figure 1 shows the basic components of a general image processing system. Basically an image processing system works in four phases in succession: (1) sensing the image, (2) digitizing the image, (3) processing the image and then (4) displaying the result.

Image Sensor Device: An image sensor device takes the light energy coming from the scene and transforms this light energy into an intensity image.

Two different technologies are used in image sensor:

- (i) Photo electronic
- (ii) Photochemical

In a photo electronic technology, image detection, formation and recording process are separate entity but the advantage of this method is that the recorded image can be easily converted to digital form on the other hand in photochemical technology, image formation and recording takes place in photographic film. Some of the image sensor devices are Still camera, CCDs (charged coupled devices), Multispectral scanner.

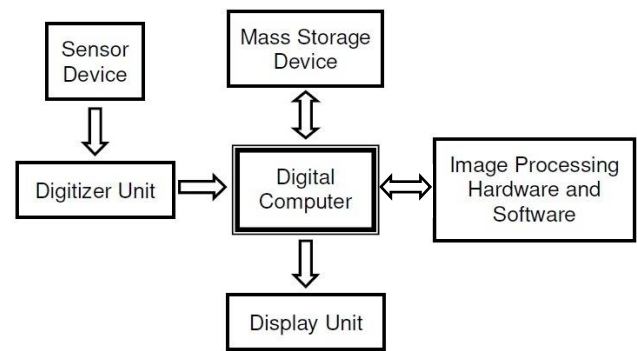


Figure 1: Basic Component of a general Digital Image Processing System

1. Digitizer: A digitizer converts an output of sensor device in the digital form. Most of the image sensors have built-in digitizer while some sensor uses external A/D convertor for digitization.

2. Digital Computer: A general purpose computer is basically used in image processing system. Specially designed high end computer systems are also used in dedicated application for achieving faster speed and better performance. Special graphics card and parallel processor are also included in those image processing systems which are designed for some special purposes.

3. Image Processing Software and Hardware: Specialized image processing hardware like digitizer, high resolution cameras, high speed ALUs, CPUs, GPUs, etc. and special sensor comes in this category. Some special purpose software packages for performing special image manipulation task under different language/ programming platform comes in this category, e.g., MATLAB, Image J, etc.

4. Mass Storage Device: It is one of the most important components of the image processing system because each image requires some space to be stored before processing in compressed and uncompressed form. Since image processing system deals with millions of images therefore adequate storage capacity is need which is provided by the mass storage devices.

Digital storage can be divided into two major categories:

- (i) Short term storage devices e.g. RAM.
- (ii) Long term storage devices e.g. high capacity HDD.

Display Unit: Display unit is basically used to show visual form of processed data stored in computer. Television, Monitor, CRT, Printer,

LCD,LED are the main Display devices used in image processing system.

III. TRANSFORMATIONS IN IMAGE PROCESSING

As shown in the figure 2 given below, digital image processing can be considered as a function that performs a transformation of the input image from one form to image in another form. Above cases are discussed below:

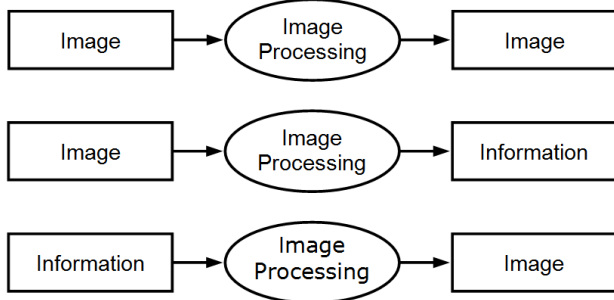


Figure 2: Transformation in Image Processing

A. Image to Image Transformations:

This helps accomplish following objectives in image processing activity:

- Image enhancement [4]
- Image restoration [5]
- Image geometry [6]

B. Image to Information Transformations:

- Image statistics histogram helps in analyzing and processing the image [7]
- Image compression [8]
- Image analysis [9] includes image segmentation [10], extracting the features in image [11], pattern recognition scheme [12]
- Computer-aided design

Basically, most image processing algorithms comprises of a few typical steps as shown in the Figure 3 below:

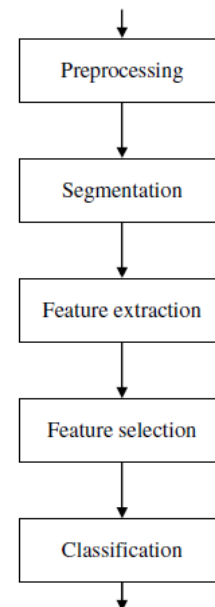


Figure 3: Steps in Image Processing Algorithms

C. Information to Image Transformations:

- Decompression from the image which is already compressed.
- Reconstruction of small parts of images to forms new original image.
- Animations Computer graphics, and virtual reality

IV. IMAGE PROCESSING TECHNIQUES

In this section, we present discussions on different types of image processing techniques:

- Image registration[36]
- Image enhancement [13]
- Image restoration [5]
- Image compression [8, 16]
- Image segmentation [10]
- Image recognition [12]
- Image smoothing [14]
- Image fusion[28]
- Steganography[33]

These image processing techniques are further discussed below:

A. Image Registration: [36-43]

Image registration is a fundamental task in image processing used to match two or more images which are taken at different time, from different sensors or different viewpoints. Image registration is the process of precisely overlaying two (or more) images of the same area through geometrically aligning common features (or control points) identified in the images. It mainly consists of four steps: (i) feature detection, (ii) feature matching, (iii) transformation function estimation and (iv) image resampling. Image registration is usually

applied in photogrammetry, remote sensing, computer vision, pattern recognition and medical image registration.

The present image registration methods can be generally divided into two broad categories: (i) area-based and (ii) feature-based methods.

(i) Area-based methods deal with the images without detecting salient features, and adopt optimization algorithms. These methods are substantial to the intensity distribution.

(ii) The feature-based methods do not directly work with image intensity values, but, instead, use salient features extracted from two images, which has been shown to be more suitable for such situations that intensity changes and complicated geometric deformations are encountered. Therefore, these feature-based methods have been widely used in remote-sensing image registration. Feature-based image registration consists of five steps: preprocessing, feature selection, feature correspondence, transformation and resampling.

Among them, feature selection, correspondence and transformation require numerous manipulation techniques, where in the most difficult one is the feature correspondence. If some correspondences are incorrect, they will produce an incorrect transformation function, which could yield totally wrong results, so a highly robust matching algorithm is needed. The process of image registration intersects with the following research areas: computer vision, pattern recognition, and remotely sensed data processing. In general, its applications can be divided into (i) multi-view analysis, (ii) multi-temporal analysis and (iii) multimodal analysis according to the manner of the image acquisition.

Image registration finds a variety of applications in computer vision, such as image matching for stereo vision, pattern recognition, and motion analysis. Unfortunately, existing techniques for image registration tend to be costly. Moreover, they generally fail to deal with rotation or other distortions of the images.

B. Image Enhancement: [4,13, 19]

Image enhancement is the method for providing the results of image to be clearer, by improving from original images so that the results are more suitable for display or further image analysis. It helps in removing noise,

sharpening the image, or brightens an image, making it easy to identify key features. The process of enhancing the quality of images from the original image by removing the noise, provide the enhanced image by sharpening the original image and increasing contrast in image. Basic steps involved in image enhancement methods are presented in the figure 4 below and the example of an image enhancement is shown in figure 5:

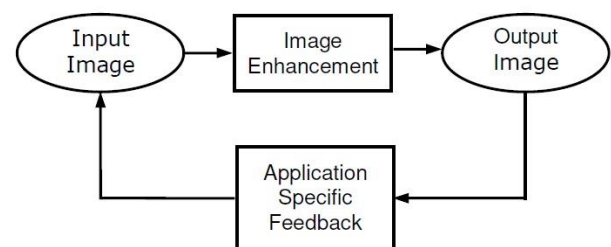


Figure 4: Image Enhancement Techniques

There are two categories of Image enhancement techniques:

- Spatial domain method (modification or aggregation of pixels that forms the image).
- Frequency domain method (enhancing the image in a linear manner), positioning invariant operator. The 2-Dimensional convolution is performed in frequency domain with Discrete Fourier Transform (DFT).



Figure 5: Examples of Image Enhancement

C. Image Restoration: [5, 18]

Restoring the clear image from the degraded or corrupted image is provided by the technique called image restoration. Corrupted/Blur images are due to noisy, blur images or camera misfocus. Blurring occurs due to formation of bandwidth reduction of an ideal image caused by imperfect image formation process. Thus the images will be restored into original quality by reducing the physical degradation.

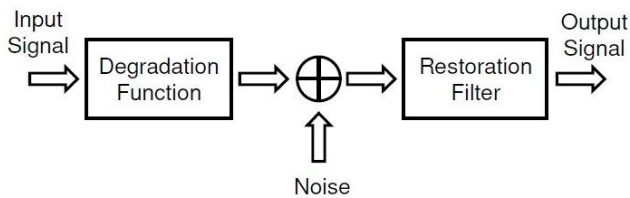


Figure 6: Image Restoration Techniques

Categories in image restoration technique:

Image restoration technique is classified into two types depending upon the degradation of the image. If information about degradation is known previously, then deterministic method of image restoration can be used. If it is not known then the stochastic method of image restoration has been introduced.

Degradation model

Distortion is due the imperfection in the imaging system that occurs mainly involved in stored images. This problem leads to severe due to random noise involved in the imaging system. Degradation operation works on input image $f(x, y)$ to lessen a degraded image $g(x, y)$.

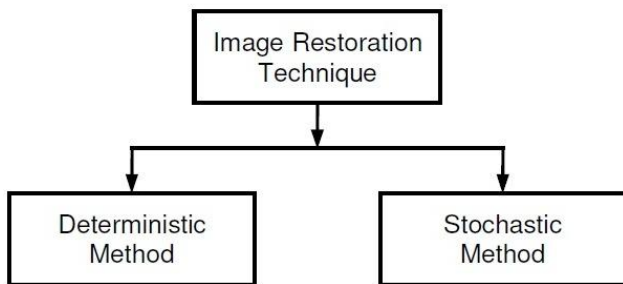


Figure 7: Categories of Image Restoration Methods

Image restoration technique is classified into two types depending upon the degradation of the image. If information about degradation is known previously, then deterministic method of image restoration can be used. If it is not known then the stochastic method of image restoration has been introduced.

D. Image Compression: [15, 17]

Image compression is minimizing the size of bytes of a image file without degrading the quality of the image in order to obtain the image in more clarity. The reduction in file size allows more images to be stored in a given amount of disk or memory space. And also reduces the time during sending of images via networks or downloading from web pages.

There are many compression techniques in practice. Broadly, image compression techniques can be categorised as:

- Lossy Image Compression, and
- Lossless Image Compression

Lossy Compression:

Compression techniques that involves the loss of information included in used at low bit rates, and used in application streaming media and internet telephony.



Figure 8: Examples of Image Compression

Lossless Compression:

In image compression, there is no loss in information regarding image, during compression of a text file or program can be compressed without any errors and the application includes images stored in medical repository, text file compression, and technical drawings.

E. Image Segmentation: [10]

Image segmentation is the process of dividing the image in to different segments, so as to change the image representation into something more meaningful and easy to analyze form. Image processing and image analysis are two different approaches for dealing with image. Image processing take the image as input and produce an image of better quality while in image analysis, a detail description of the image is produced. Segmentation is one of the important steps in image analysis. Image segmentation basically divides the image into different meaningful part or region.

Segmenting or partitioning the original image with some defined pixels into number of regions for the purpose of image analysis, depicts the features hidden in the normal image and object recognition, undefined boundary estimation, textures and motions. It is based on region and edges of image, segmentation is carried out.



Figure 9: Examples of Image Segmentation

The main problem with the segmentation is that it is not necessary that all the time the extracted region or segmented region contain some useful information regarding the object of the scene and therefore there is no general segmentation algorithm is possible which can work reasonably in all situations. In most of the cases user has to develop the segmentation algorithm as per the need of the application. In image segmentation, characteristics of pixels like texture, intensity, color etc. of the segmented region are similar or homogeneous in nature. A good segmentation must possess following properties:

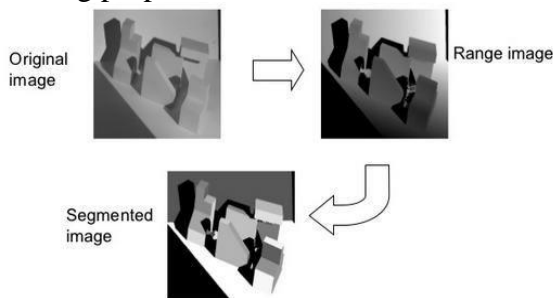


Figure 10: Image Segmentation Process

- (i) The characteristics of the image like intensity, color, texture etc must be uniform and homogeneous in the segmented part of the image.
- (ii) Boundaries of each segmented part must be clear and distinct.
- (iii) The characteristics of the adjacent region must be different from each other.

- (iv) Each regions has clear interiors and free of small holes.

F. Image Recognition: [12]

Image recognition technique involves in recognizing/ identifying and detecting features such as objects in video or images. During the recognition mechanism, images from the database are compared with the current image, if the match is found then further execution of process will be carried out in real time application. It helps in authentication and authorization process.

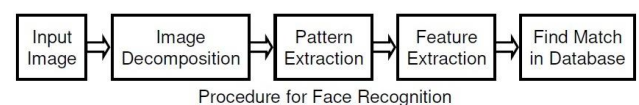
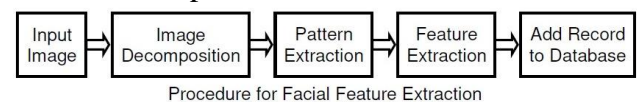


Figure 11: Steps in Image Recognition

Method in image recognition

1. Pattern recognition-recognize any patterns of pixels in image.
2. Face recognition- focuses on detecting face in image
3. Optical character recognition-detects text and read it.



Figure 12: Login with Pattern and Face Recognition

G. Image Smoothing: [14]

With this smoothing technique, noise can be reduced from the image. Image may contain noisy data such as dots, blur, speckles, stains, using this smoothing technique that acts as filter to remove the noisy data. It works Based on the low pass filter, which helps in decreasing the great difference between pixel values by averaging nearby pixel value. Considering single value calculated for an image such as median and average value.

Smoothing operations:

1. Linear filter
2. Non-Linear filter

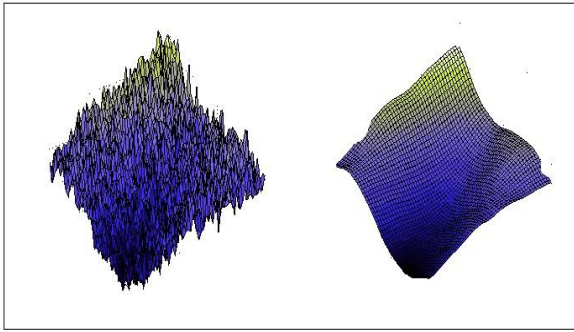


Figure 13: Image Smoothing Technique

H. Image Fusion: [28-32]

The term fusion means in general an approach to extraction of information acquired in several domains. The goal of image fusion (IF) is to integrate complementary multisensor, multitemporal and/or multiview information into one new image containing information the quality of which cannot be achieved otherwise. The term quality, its meaning and measurement depend on the particular application.

Image fusion, also called pan-sharpening, is a technique used to integrate the geometric detail of a high-resolution panchromatic (Pan) image and the color information of a low-resolution multispectral (MS) image to produce a high-resolution MS image. This technique is particularly important for large-scale applications.

Image fusion has been used in many application areas. In remote sensing and in astronomy, multisensor fusion is used to achieve high spatial and spectral resolutions by combining images from two sensors, one of which has high spatial resolution and the other one high spectral resolution. Numerous fusion applications have appeared in medical imaging like simultaneous evaluation of CT, MRI, and/or PET images. Plenty of applications which use multisensor fusion of visible and infrared images have appeared in military, security, and surveillance areas. In the case of multiview fusion, a set of images of the same scene taken by the same sensor but from different viewpoints is fused to obtain an image with higher resolution than the sensor normally provides or to recover the 3D representation of the scene. The multitemporal approach recognizes two different aims. Images of the same scene are acquired at different times either to find and evaluate changes in the scene or to

obtain a less degraded image of the scene. The former aim is common in medical imaging, especially in change detection of organs and tumors, and in remote sensing for monitoring land or forest exploitation. The acquisition period is usually months or years. The latter aim requires the different measurements to be much closer to each other, typically in the scale of seconds, and possibly under different conditions.

I. Steganography: [33-35]

Since the rise of the Internet one of the most important factors of information technology and communication has been the security of information. Cryptography was created as a technique for securing the secrecy of communication and many different methods have been developed to encrypt and decrypt data in order to keep the message secret. Unfortunately it is sometimes not enough to keep the contents of a message secret, it may also be necessary to keep the existence of the message secret. The technique used to implement this, is called steganography.

Steganography is the art and science of invisible communication. Steganography is the process of hiding a secret message within a larger one in such a way that someone cannot know the presence or contents of the hidden message. This is accomplished through hiding information in other information, thus hiding the existence of the communicated information. The word steganography is derived from the Greek words “stegos” meaning “cover” and “grafia” meaning “writing” defining it as “covered writing”.

There are different kinds of steganography. Almost all digital file formats can be used for steganography, but the formats that are more suitable are those with a high degree of redundancy. Redundancy can be defined as the bits of an object that provide accuracy far greater than necessary for the object’s use and display. The redundant bits of an object are those bits that can be altered without the alteration being detected easily. Image and audio files especially comply with this requirement, while research has also uncovered other file formats that can be used for information hiding. Figure 14 shows the four main categories of file formats that can be used for steganography.

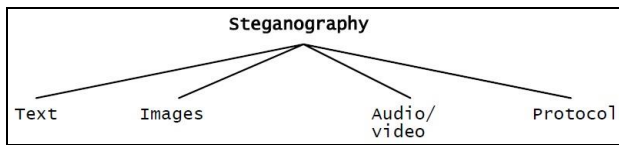


Figure 14: Different Types of Steganography

The basic structure of Steganography is made up of three components: the “carrier”, the message, and the key. The carrier can be a painting, a digital image, an mp3 audio file, even a TCP/IP packet among other things. It is the object that will ‘carry’ the hidden message. A key is used to decode/decipher/discover the hidden message. This can be anything from a password, a pattern, a black-light, or even lemon juice.

Hiding information in text is historically the most important method of steganography. An obvious method was to hide a secret message in every nth letter of every word of a text message. It is only since the beginning of the Internet and all the different digital file formats that it has decreased in importance. Text steganography using digital files is not used very often since text files have a very small amount of redundant data.

In image steganography the information is hidden exclusively in images. Although related, Steganography is not to be confused with Encryption, which is the process of making a message unintelligible—Steganography attempts to hide the existence of communication.

As shown below in figure 15, digital watermarking is a special case of information hiding.

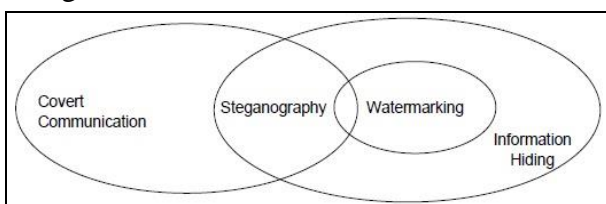


Figure 15: Steganography and its related fields.

Digital watermarking is the process of embedding information into digital multimedia content such that the information (the watermark) can later be extracted or detected for a variety of purposes including copy prevention and control. Digital watermarking has become an active and important area of research, and development and commercialization of watermarking techniques is being deemed essential to help address some

of the challenges faced by the rapid proliferation of digital content.

V. SOFT-COMPUTING TECHNIQUES FOR DIP

In this section, we present discussions on Soft Computing techniques for digital image processing applications [20, 21]. Soft Computing is an emerging field comprising techniques such as fuzzy logic, neural computing, evolutionary computation, and machine learning. The intention of this survey is to study the current state-of-the-art approaches of soft computing techniques in image processing, computer vision and related applications. The prime objective of integrating soft-computing tools into the digital image processing domain is to tolerate the imprecision, uncertainty, approximate reasoning and partial truth in order to achieve tractability, robustness, low solution cost, and close resemblance with human like decision making. This survey work studies the relevance of integrating different soft computing tools for designing of efficient image processing and analysis systems based on their merits. At this juncture, fuzzy logic (FL), artificial neural networks (ANN), genetic algorithms (GA), particle swarm optimization (PSO) are few key elements of soft-computing tools where FL provides algorithms for dealing with imprecision and uncertainty, and computing with words, ANN the machinery for learning and adaptation; and GA/PSO is used for optimization and searching.

VI. DEDICATED AND SPECIAL PURPOSE HARDWARE

In this section, we present discussions on dedicated and special purpose hardware and processors for image processing applications [22, 23, 24].

Digital image processing refers to processing or manipulation of digital image with the help of digital computer or other digital hardware, by converting the image in to set of integers otherwise known as pixels (or picture elements). Drop in market price of digital computers and hardware elements and enhancements in the speed and accuracy has made the job easier to manipulate and enhance images. Downward market trend indicates that the cost of digital equipment will continue to decline further. The advancement in the new technology and easy availability of parallel processing hardware with

the help of low cost microprocessor, multi-core processor, GPUs, reconfigurable devices along with the availability of high resolution charge coupled devices (CCDs) helps in promoting the digital image processing [25, 26, 27]. Continual advancement in the digital image processing field has made the area of coverage of this field large day by day. Several medical diagnosis has become easier with the help of digital imaging techniques. It is also well suited for remote sensing program. Thus considering the easily available cheap hardware and ever increasing extent of this field, it is certain that the digital image processing will play key role in future.

VII. CONCLUSION

Image processing applications targeted to operate in real-time are inherently of embedded systems in nature. Since the acceleration for video image segmentation, morphological operation, feature extraction, video capturing, character recognition, etc. are better realised in hardware. While the equally important image processing operations better realised in software are image classification, dynamic noise filtration, image compression, etc. This paper presents a review on various types of techniques of image processing such as image registration, restoration, image enhancement, image segmentation, image recognition, image fusion and image steganography has been discussed briefly and also provides clear view of applications used in image processing. The easily available cheap hardware and ever increasing extent of this field, it is obviously suggesting that the digital image processing will play key role in challenging future world of development avenue for researchers, academicians, scientist and industries to explore these area's cost effective products in market.

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