CHAPTER 1

INTRODUCTION

PREVIEW

The aim of digital image processing is to develop potential information for human interpretation and processing of image data for storage, transmission, and representation for autonomous machine perception. The quality of image degrades due to contamination of various types of noise. Impulse noise, additive white Gaussian noise, Rayleigh noise, etc. corrupt an image during the processes of acquisition, transmission and reception and storage rescue. For an important and useful processing such as image segmentation and object recognition, and to have very good visual display in applications like television, digital camera, photophone, etc., the acquired image signal must be noise-free and made deblurred. Image deblurring and image denoising are the two sub-areas of image restoration. In modern research work, efforts are made to propose efficient filters that suppress the noise and preserve the edges and fine details of an image as far as possible in a various range of noise level.

The following topics are covered in this chapter:

- Fundamentals of Digital Image Processing
- Background
- Applications
- Motivations
- Statements of the problem
- Organization of the thesis
- Summary
1.1 FUNDAMENTALS OF DIGITAL IMAGE PROCESSING

A major portion of information received by a human being from the environment is visual. Hence, processing visual information by computer has been drawing a very important consideration for researchers over the last few decades. The process of receiving and analyzing visual information by the human species is referred to as sight, perception and understanding. Similarly, the process of receiving and analyzing visual information by digital computer is called digital image processing [49].

An image may be described as a two-dimensional function $f(i,j)$, where $i$ and $j$ are spatial coordinates. Amplitude of $f$ at any pair of coordinates $(x,y)$ is called intensity or gray value of the image. When spatial coordinates and amplitude values are all finite, discrete quantities, the image is called digital image [60]. Each element of this matrix (2-D array) is referred as picture element or pixel. Image Processing (IP) is a branch of study where a 2-D image signal $f(i,j)$, is processed either directly (spatial-domain processing) or indirectly (transform-domain processing). IP and Computer vision are two separate fields with just a narrow boundary between them. In case of IP, both input and output are 2-D images, whereas the output of a Computer vision system is necessarily not an image rather but some attributes of it.

The ultimate goal in computer vision is to use the computer to follow human vision, including performance of some analysis, judgment or decision making or performing some mechanical operation (robot motion) [11]. Figure 1.1 shows a typical image processing system [49, 60].
Figure 1.1 Basic block diagram

Following is the list of the most common image processing functions of any image processing system.

- **Image Representation**
- **Image Transformation**
- **Image Enhancement**
- **Image Restoration**
- **Color Image Processing**
- **Transform-Domain Processing**
- **Image Compression**
- **Morphological Image Processing**
- **Image Representation and Description**
- **Object Recognition**

For the first seven functions, the inputs and outputs are images, whereas, for the rest three, the outputs are attributes of the input images. With the exception of image acquisition and display, most image processing functions are usually implemented in software. Image processing is characterized by specific solutions; hence the technique that works well in one area may be inadequate in another.
Image processing begins with the image acquisition process. Two elements are required to acquire digital images. The first one is a sensor; it is a physical device that is sensitive to the energy radiated by the object that has to be imaged. The second part is called a digitizer. It is a device for converting the output of the sensing device into digital form.

For example, in a digital camera, the sensors produce an electrical output proportional to light intensity. The digitizer converts the outputs to digital data noises are introduced during the process of image acquisition.

Image processing may be performed in spatial or transform-domain. Different transforms (e.g. Discrete Fourier Transform (DFT) [18], Discrete Cosine Transform (DCT) [14, 16], Discrete Hartley Transform (DHT) [50], Discrete Wavelet Transform (DWT) [60-63], etc., are used for different applications.

*Image enhancement* is among the simplest and most appealing areas of digital image processing [23, 71]. Basically, the idea behind enhancement techniques is to bring out detail that is obscured, or simply to highlight certain features of interest in an image. A familiar example of enhancement is when the contrast of an image is increased so that it looks better. It is important to keep in mind that image enhancement is a subjective area of image processing. On the other hand, image restoration is very much objective. The restoration techniques are based on mathematical and statistical models of image degradation. Denoising [20, 54] and deblurring tasks come under this category.

*Image restoration and filtering* is one of the prime areas of image processing and its objective is to recover the images from degraded observations. The techniques involved in image restoration and filtering are oriented towards modeling the degradations and then applying an inverse operation to obtain an approximation of the original image. The use of color in image processing is motivated by two principal factors. First, color is a powerful descriptor that often simplifies object identification and extraction from scene. Second, humans can discern thousands of color shades and intensities, compared to shades of gray.
The first encounter with digital image restoration in the engineering community was in the area of astronomical imaging during 1950s and 1960s. The aim of the mission was to record many incredible images of the solar system. However, the images obtained from the various planetary missions of the time were subject to much photographic degradation. This mission required a huge amount of money. The degradations occurred due to substandard imaging environment, rapidly changing refractive index of the atmosphere and slow camera shutter speed relative to spacecraft. Any loss of information due to image degradation was devastating as it reduced the scientific value of these images.

In the area of medical imaging, image restoration has certainly played a very important role. Restoration has been used for filtering out noise in X-rays, mammograms and digital angiographic images. Another application of this field is the use of digital techniques to restore old and deteriorated films. The idea of motion picture restoration is perhaps most often associated with the digital techniques used not only to eliminate scratches and dust from celluloid films of old movies, but also to colorize black-and-white (gray-scale) films.

Digital image restoration finds use in many other applications also. Just to name a few, it has been used to restore blurry X-ray images of aircraft wings to improve quality assessment procedures. It is used for restoring the motion induced effects present in still composite frames and more generally, for restoring uniformly blurred television pictures. Digital restoration is also used to restore images in automated assembly / manufacturing processes. Many defense-oriented applications require restoration, such as guided missiles, which may obtain distorted images due to the effects of pressure differences around a camera mounted on the missile.

Digital images, which are 2-D signals, are often corrupted with many types of noise, such as additive white Gaussian noise (AWGN) which is referred to as additive noise and substitutive noise such as, salt-and-pepper noise (SPN), random-valued impulse noise (RVIN), multi-level noise during the processes of acquisition, transmission and reception, and storage and retrieval. The impulse
noise is substitutive noise, i.e. the corrupted pixel value does not depend on the original pixel value, whereas additive Gaussian noise modifies the original pixel value with uniform power in the whole bandwidth and with Gaussian probability distribution. Impulse noise comes under two categories: (1) fixed-valued impulse noise and (2) random-valued impulse noise. Under fixed-valued impulse noise, the noise may be unipolar or bipolar. On many occasions, an image is observed to be corrupted with bipolar fixed value impulse noise. A fixed-valued bipolar impulse noise is called salt-and-pepper noise (SPN) due to its appearance. The malfunctioning pixels in camera sensors, faulty memory locations in hardware, or transmission of the image in a noisy channel, are some of the common causes for impulse noise [38, 65, 86]. The intensity of impulse noise has the tendency of either being relatively high or low. Due to this, when the signal is quantized to „L“ intensity levels, the corrupted pixels are generally digitized into either minimum or maximum values in the dynamic range, these pixels appear as white or black dots in the image. This may severely degrade the image quality and cause some loss of image information. Keeping the image details and removing the noise from the digital image is a challenging part of image processing [29, 26, 28].

It is difficult to suppress AWGN since it corrupts almost all pixels in an image. The arithmetic mean filter, commonly known as Mean filter [37-39], can be employed to suppress AWGN but it introduces a blurring effect [16-20, 22]. Efficient suppression of noise in an image is a very important issue. Conventional techniques of image denoising using linear and nonlinear techniques have already been reported and a sufficient literature is available in this area [49, 60, 102, 38, 109].

A number of nonlinear and adaptive filters are proposed for denoising an image. The aim of these filters is to reduce the noise as well as to retain the edges and fine details of the images [23-28, 54-69]. However it is difficult to achieve both the objectives and the reported schemes are not able to perform in both aspects. Hence, various research workers are actively engaged in developing better filtering schemes using latest signal processing techniques. The present doctoral research work is focused on developing quite efficient image denoising filters to suppress
impulse and Gaussian noise quite effectively without yielding much distortion and blurring.

1.2 BACKGROUND

Over the last three decades, an expansive growth has been witnessed in both the diversity of techniques and range of applications of image processing. Images are encountered everywhere in our life. Basically, an image is a projection of a three-dimensional (3D) scene into a two-dimensional (2D) projection plane. A monochrome image \(O\) may be defined as a two-dimensional function consisting of pixels \(o(i, j)\) where \(i\) and \(j\) are the spatial coordinates and function value \(o\) at the coordinates \((i, j)\) represents the intensity or gray level of the image at that location. When \(i\), \(j\) and function value \(o\) all are discrete and finite quantities for the entire image, the image is referred to as a digital image [60].

For color images, the pixel is represented by a vector \(o(i, j)\) for a particular location, which has three intensity values \(o_{(1)}(i, j)\), \(o_{(2)}(i, j)\) and \(o_{(3)}(i, j)\) each corresponding to red, green and blue colors, respectively [81]. The field of digital image processing refers to the use of computer algorithms to extract useful information from digital images. The entire process of image processing may be divided into three major stages:

(i) **Image acquisition**: converting 3D visual information into 2D digital form suitable for processing, transmission and storage.

(ii) **Processing**: improving image quality by enhancement, restoration, etc.

(iii) **Analysis**: extracting image features; quantifying shapes and recognition [18].

In the first stage, input is an image scene, and output is a corresponding digital image. In the second stage of processing, both input and
output are digital images where the output is an improved version of the input. In the final stage, input is still a digital image but the output is description of the contents. A block diagram of different stages is shown in Figure 1.2.

**Figure 1.2 Steps in image processing**

### 1.3 APPLICATIONS

Image processing has a broad spectrum of applications and can be surveyed using domains where images are used. The applications of image processing covering different areas are as follows:

(i) **Medicine**: X-rays [115], CT-scan, MRI [74], Ultrasound, etc. for detecting various diseases.

(ii) **Forensics**: Identifying physiological characteristics such as face [42], iris, fingerprints [89], palm, etc.

(iii) **Remote Sensing**: Meteorological applications such as weather forecasting, locating natural resources- forests, water, etc.

(iv) **Communication**: Watermarking [73], Video conferencing, HDTV [85], etc.

(v) **Industry automation**: Automated visual inspection in aerospace, food, textile [85] etc.
(vi) Traffic control: Analyzing pictures taken by cameras for crowd control [62].

(vii) Defense: Night vision devices, RADAR [24], etc.

(viii) Robotics: Pilot-less vehicles, surface measurements [133], etc.

1.4 MOTIVATION

There are numerous specific motivations for image processing but many fall into the following two categories: (i) the removal of unwanted signals that corrupt the image and (ii) extraction of information by rendering it into more useful form. Image de-noising falls into the first category and is very important for not only visual enhancement but also to facilitate automatic processing. Digital image enhancement is a field of engineering that studies methods for recovering an original scene from degraded observations [60,50]. Often, the captured image may not be of good quality due to because of factors such as noise, poor brightness, contrast, blur, or artefacts. Figure 1.3 shows the block diagram for image degradation and restoration process in which degradation function is noise $\eta(i,j)$ location $(i,j)$, that operates upon image pixel $o(i,j)$, to generate degraded pixel. The degraded pixel is then processed by a denoising filter to provide an estimate at the $x(i,j)$ : $y(i,j)$ of the original value. In general, the more we know about the degradation functions is known, the closer will be $y(i,j)$ to $o(i,j)$.

![Image degradation and restoration process due to noise only](image.png)
Several techniques have been proposed over the years for image filtering. Linear filtering techniques have been the methods of choice for many years on account of their mathematical simplicity and existence of a unifying theory for their design and implementation. However, most of these techniques assume a Gaussian model for the statistical characteristics of the underlying process and hence they try to optimize the parameters of a system suitable for such a model. Classical image filtering techniques are generally based on averaging, transform domain filtering and contrast enhancement, with most of them being linear.

In the case of image processing, however, linear techniques are proved inadequate as they cannot cope with the nonlinearities of the image formation model and do not take into account specialties of human visual systems. These methods, therefore, often produce blurred images and are insensitive to impulse noise. Image signals are composed of flat regional parts and abruptly changing areas such as edges, which carry important information for visual perception. Thus, over the last fifteen years, nonlinear approaches have been found to be more effective for this purpose. They are able to suppress non-Gaussian and signal dependent noise to preserve important signal elements such as edges and fine details and eliminate degradations occurring during signal formation or transmission through nonlinear channels.

Filters having good edge and image detail preservation properties are highly suitable for image filtering and enhancement. New algorithms and techniques, which can take advantage of the increase in computing power and can handle more realistic assumptions, are needed. Thus, the development of nonlinear filtering techniques, which perform equally well under a wide variety of applications, is of great importance.
1.5 STATEMENT OF THE PROBLEM

When image is degraded only by noise, the restoration can be done by using suitable de-noising algorithms. For this purpose, the nature of the noise must be known. In an image processing system, noise can be divided into three main categories: Gaussian noise (naturally occurring), sensor induced noise (photon counting, speckle etc.) or processing noise (quantization, transmission etc.). Accordingly, the following noise models are used in image processing literature:

(i) Additive, random and independent of image (amplifier noise).

(ii) Additive, random and dependent on image (Speckle noise).

(iii) Random but not fitting into above two models (Salt & pepper, Random valued impulse noise).

In the present research work, focus is only on the impulse noise and the Gaussian noise removal that fits into the third type. As the performance of the filtering system is primarily governed by the precision with which the system can identify the noisy pixels correctly, the main objective of this work is to develop impulse noise detectors for fixed valued as well as random valued impulses. Once the noisy pixel is identified correctly, next goal is to restore its original value. Several algorithms are available for monochrome images which perform satisfactorily. However, for color images, most of the algorithms either restore only the intensity or color of the pixel correctly. Thus, the second objective is to develop a new filtering algorithm that can effectively restore the intensity as well as color. In short, the problems undertaken for research are as follows:

- The study of the existing methods for impulse noise removal including random valued impulse noise, salt and pepper and fixed valued impulses and the analysis of their performance and identification of the limitations in order to design some new algorithms.
• Development of a suitable method that can effectively detect the presence of mixed Gaussian-impulse noise and remove it.

• In case of random valued impulse noise, the difference between the noisy pixels and its neighbors is small due to which noise filtering is difficult. Therefore, the goal is to develop some algorithms which can effectively employ the following strategies to deal with this type of noise:

  (i) Widen the gap between pixel under observation and its neighbors.

  (ii) Use of neighborhood information extracted in terms of suitable image dependent local features.

• To extend the algorithms developed for impulse detection of color images and further improve their performance by exploiting the correlation among different channels.

• To develop a filter for color images that can removal the noisy components of the color image pixel such that its intensity and color are restored effectively.

Therefore, the following problem is taken up.

**The problem:** To develop some novel efficient restoration algorithms for images corrupted with impulse and Gaussian noise. A brief overview of fundamentals of spatial-domain filtering is presented in the next chapter for ready reference.
1.6 ORGANISATION OF THE THESIS

As the impulse and Gaussian noise removal is an important pre-processing task in almost all image processing applications, a very rich literature is available in this area. The work carried out during the research is organized as follows:

Chapter 1 defines the problem, provides the motivation for carrying out the present research work and gives an overview of the entire work covered in the thesis. In Chapter 2, a brief review of the various approaches used for impulse and Gaussian noise removal schemes is presented. The important issues related to various schemes are also discussed. In Chapter 3 digital color image systems, and also discussed color image system elements and color filtering frameworks, image formation, mathematics of color reproduction.

Chapter 4 describes deals with the impulse and Gaussian noise removal from color images, and also mixed with impulse and Gaussian noise removal from color images. A new fuzzy filtering scheme is introduced which is based on component wise detection of noisy components and a new color filter which is developed to correct the intensity as well as color of the noisy components of the pixel. For filtering the noisy components of the pixels, the new color filter developed in this Chapter is used to give a better combination of intensity and color. All the filtering schemes proposed in above chapters are examined through extensive simulations and results are compared with several existing schemes.

Chapter 5, presents a fixed valued impulse noise removal scheme is presented. To develop new fuzzy filters for Adaptive Statistical Quality based Filtering Technique (ASQFT). The proposed scheme is based on a dual detector for identification of noisy pixels and two variants of median filter for restoration according to the noise density. The performance of the proposed algorithm is given in terms of mean square error (MSE) and peak signal to noise ratio (PSNR) and it is compared with other exiting filters like
Chapter 6 focuses on removal of random valued and fixed valued impulse noise from digital color images. The proposed algorithm produces better results visually and also MSE and PSNR are better compared to the existing video algorithms.

Chapter 7 summary concludes the dissertation with overall findings of the present study. A summary of research contribution and the scope for future studies are also incorporated in this chapter.

1.7 SUMMARY

In this Chapter, the basics of Digital Image Processing, sources of noise and different types of noise, review of some existing methods and some commonly used applications of image processing are discussed. After a brief literature review, the doctoral research problem is evolved.

Extensive studies of well known and high-performing image denoising filters available in literature are presented in the next chapter where as the proposed algorithms are discussed in subsequent chapters. Finally, the dissertation is concluded in Chapter 7.