CHAPTER 1

INTRODUCTION AND SCOPE OF THE WORK

1.1 Digital Image Processing and its Scope

Digital image processing [1-18] has made a great impact in the field of science and engineering specially in artificial intelligence [2]. With the tremendous advancement of the technology associated with the recent digital computers, there has been a considerable growth of interest in the challenging task of building machines for visual perception and recognition that can perceive, learn, think and take decisions. To accomplish such unsurmountable task, one must understand the logistics involved in the process of human visual perception and recognition [19,20]. One needs to carefully analyse and implement various steps involved in the process of human vision and intelligent pattern recognition. Perhaps, the discrete structure of the visual receptors in the retina (rods and cones) of the eye where the human vision begins gave an impetus in the emergence of this new field, because the human vision itself is a process involving digital image processing. When the visual information is received by human visual system, the process is referred as sight, perception or understanding. When a computer receives and processes such visual information, the process is referred to as computer or digital image processing and recognition.

A great importance has been imposed in this field, because 75% (approx) of the information received by the human being is visual[3,20]. The field of digital image processing had experienced a major impetus when the fast Fourier transform (FFT) algorithm [23-31] had come into existence in handling such two dimensional data analysis and when the cost of the semiconductor integrated circuit (IC) had gone down. The low cost IC's for refresh memory had helped in achieving newer image display systems. The processing and storage of the large data would be constrained, if the technology for doing so were still tied to the technology of 1965.

There has been increasing acceptance of the notion that the human visual system performs a variety of parallel operation on input scene. This gives the impetus for the development of parallel processors [32] and real time digital image processing system [33] based on the experience gained by the human visual system and on the phenomena related to natural processes. All these requirements demand a simpler algorithm [138-139] that requires less computation time and memory so that the real time implementation is possible to supplement the human viewing ability by intelligent machine. By this process, the initial concept of frequency domain approach is becoming outdated day by day and the concept of spatial domain approach is becoming more and more efficient, popular and compatible to natural processes.

In a broad sense, an image is nothing more than a two-dimensional function [34] whose variation in gray scale describe pictorial information. The field of digital image processing deals with the manipulation of such data mainly for two principle application areas, namely, the improvement of pictorial information for human interpretation, and increasing the probability of correct detection and recognition through autonomous systems. There are various application areas, where real time image processing systems [33] are becoming essential. In interactive applications, such as biomedical image analysis [37-41] and industrial automation [42], real time techniques are important not only in terms of increasing productivity but also for improving quality by reducing operator's error associated with visual feedback delays. Such industrial applications include product assembly and testing by automated inspection of pictures generated by infrared radiation, visible radiation, X-rays and ultrasonics. In applications like robotics and military systems, real time image processing techniques are often required in a preprocessing stage in order to increase the probability of correct pattern detection and recognition. The applications are generally characterised by large data throughput requirement which can only be met by hardware capable of operating in real time.

Biomedical applications of image processing involve correct interpretation of radiographs, cell images and tissue micrographs. In metallurgical and geological sciences, digital image processing finds applications in the analyses of fractographic pictures and electron microscopic images. In computer and information sciences it deals with automatic reading and recognition of alphanumeric characters, drawings, geometrical configurations and pictures etc. In natural resource estimation, it deals with algorithms for automatic interpretation of satellite and aerophotos. Gardner has presented a number of such applications in his edited book [55].

The above mentioned applications need techniques for enhancing pictorial information for human interpretation and analysis. Image enhancement techniques have been used to process degraded images depicting unrecoverable objects. There have been instances in archeology, where blurred images which were the only artifacts lost or damaged after being photographed, have been successfully deblurred enhancing the pictorial informations for visual interpretation. In physics and related fields, images of experiments in high energy plasmas or electron microscopy [57] are routinely enhanced by computer techniques. Image enhancement technique has also been used successfully in military recognizance, astronomy [64], and nuclear science [65]. Quality improvement of pictorial information by enhancement technique started since 1920 when the digitised newspaper pictures [66-68] were transreceived between London and New York. It received more importance when the Jet Propulsion Laboratory was assigned the task of providing television coverage of man's landing on moon in the year 1964. Since then, many papers have been published giving various techniques to improve the pictorial information. But the ultimate goal is yet to be reached.

1.2 Scope of the present work

The enhancement process has long been considered irreversible in nature where the objective has been specified as a technique to process a given image so that the resulting image is more suitable than the original for specific application. The term "specific" is thus problem oriented. Here the main aim is to extract pictorial information either for human interpretation or for improving the possibility of correct detection and recognition using autonomous system. When one is interested with the first aim, human being becomes the part of the processing system and hence the psychopictorial phenomenon involved should be considered. The practicability and compatibility with human perceptual processing through vision and with the natural processes of degradation should be given importance by interfacing with a matched enhancement algorithm in all such cases.

Any type of quality improvement is being considered as enhancement. This is to be questioned. Whenever, one has to process a given image, one must look for the type of overall degradation. The degradation may be due to the low contrast, where almost all the gray levels are closely clustered giving illusion of uniform gray tone. In such cases, the ratio of high to low frequency Fourier components are low enough producing poor visibility. The degradation may also be due to extra-high contrast having low image details. Such over-enhancement provide only few edge informations, but most of the local details are lost in the wide uniform background.

To extract the details from such inferior quality image, the inverse process has to be applied. The experimental image sample considered by Stockham [45] is a typical inferior quality image having details obscured by the glare of the excessive light. A doubt remains to be solved is whether such an experimental image should be improved using forward enhancement process or the reverse process. The author felt a need for reverse process for such images and he likes to call it deenhancement [139]. With this deenhancement process, the highly enhanced image having extra high contrast and having low image details can be brought back nearer to the best possible image of any natural scene as viewed by any human being.

With the introduction of this new concept [139], the importance of enhancement process has increased manifold. By this reversible enhancement deenhancement (RED) process, the generalisation of the enhancement technique is further strengthened by encompassing the problem which is difficult to be solved by the irreversible enhancement process. The proposed technique is expected to encompass almost all the methods proposed by the various researchers for image contrast enhancement for viewing interpretation. As there is no standard mathematical specification to evaluate the quality of the desired enhanced image, one has to depend on the subjective evaluation of the individual viewers. This evaluation criterion needs a simple, powerful and fast enhancement algorithm.

The objective of this thesis is to present the gradual developments carried out by the author in his recent works [137-150] out of which some of the initial results have already been published. The thesis contains the theoretical and experimental investigations carried out demonstrating the effectiveness of the ideas mentioned above. An exhaustive experimentation of the proposed algorithm has been carried out on a small standard experimental image. The author had to work with minimum configuration of the computer installation (IRIS-80 Computer at Variable Energy Cyclotron Centre, Bhabha Atomic Research Centre, Calcutta) having line printer output with over printing facility as the only display device. However, this had provided great impetus to develop a most effective algorithm to improve the viewing ability by using RED process. This had also provided guarantee of avoiding confusion with the built-in contrast of the T.V. monitors, as the display is taken with line printer output rather than on T.V. screen. Formulation of transformation function and their implementation show the ingenuity which provides a simple but powerful technique giving enough encouraging results.

In Chapter 2, an extensive literature survey has been carried out to outline those techniques which are classic (i.e. have been of research and application interest for last 10-15 years) or have made a great impact in a short period of time by virtue of their importance [43-49]. There are various ways of classifying the existing techniques [16-18]. Transform domain (Fourier or Hadamard) [33] and spatial domain are the two main categories [1-5]. The superiority of the direct contrast transformation techniques [3] and the enhancement using fuzzy set [48-54] has been focussed. This has been further stressed by introducing the concept of nonlinear degradation that occur in most of the inferior quality image. Due to the lack of mathematical evaluation criterion for image quality, importance of human subjectivity can not be ignored, rather it helps to develop an improved algorithm.

The essence of the basic concept on which author's work has been carried out is elaborated in Chapter 3. Some of the basic concept underlying the natural process of degradation has been focussed. Certain general properties of psychovisual interpretation of pictorial information has been elaborated to specify certain guidelines for smooth development of the proposed algorithm. Emphasis is given to the process of nonlinear degradation and it has been shown that such degradation causes frequency distortion, variations of statistical parameters, variations of histograms and entropy etc., leading to the confusion and emergence of various problem oriented [1-5, 16-18] partial solutions. Cause and effect relations has been clearly elaborated. It has been shown that all contrast degradations may be achieved by the concept of nonlinear degradation and the solutions through RED process using S-type visual response characteristic (VRC) as transformation functions. This leads to the concept of forced enhancement [145]. Several researchers have used the phenomenon of logarithmic response of eye. But they did not consider the lower saturation effect along with upper logarithmic saturation to make it more realistic. Incorporation of such characteristic should be flexible enough such that various psychopictorial requirements are satisfied easily. So, various psychopictorial phenomena have been carefully studied before implementation. To match these psychopictorial phenomena, any algorithm proposed to aid the human visual perception, should be simple, flexible, powerful and fast. Enhancement is generally carried out to aid the feature extraction process. A flexible S-function has been shown as a powerful tool to both enhance and extract subjective features.

Implementation of the novel concept of reversible enhancement deenhancement of digital images has been presented in Chapter 4. S-function has been generated by using sinusoidal function [138] from -90° to $+90^{\circ}$. The concept of threshold [137] has been introduced to manipulate various features and their contrasts. To do this the entire gray scale has been divided into two classes or regions from black level to threshold as region 1 (-90° to 0°) and from threshold to white level as region 2 (0° to 90°). This leads to a fast computable, easily implementable, simple and powerful transformation [138]. All possible manoeuvering of transformation function from linear to extreme nonlinear, shifting up and down, left and right, symmetrical and unsymmetrical are taken care of by simple choice of few parameters. By the above choices a drastic change is possible in the enhanced image from low level to high level of enhancement. Various features may be selected and made prominent by the various choices of the thresholds.

The concept of deenhancement [139] has been implemented by the inverse transformation $g_o = T^{-1}(g_e)$ to obtain the original or deenhanced gray levels g_o from the enhanced gray levels g_e. As there is no standard mathematical criterion to evaluate the quality of the processed images and as one has to depend on subjective evaluation, various levels of contrast have been produced by forward and inverse transformations.

A further understanding of human visual perception has produced the concept of forced enhancement [145]. The implementation of the above concept has been presented in Chapter 5. When one follows logarithmic response characteristic as transformation function (T.F.) and tries to match this T.F. with that of human visual response characteristic (VRC), it produces best subjectively pleasing results. This forced matching of computer algorithm satisfies the subjective requirement maximum. The concept of forced enhancement has been implemented by using two piecewise logarithmic functions The lower saturation (whose law of response is unknown) is approximated by an inverted log function. All the possible manoeuvering of the transformation function become easy by simple choice of few parameters. This helps in the reduction of the number of parameters. The concept of deenhancement has also been implemented in this case.

The concept of fuzzy set [69-81] describes the situation in which the imprecision is due to fuzziness or vagueness rather than randomness. In humanistic problem like visual perception, specially when the human subjectivity is of prime importance, the theory of fuzzy set plays an important role. The problem under consideration has the imprecision in pictorial information due to the ambiguity of the multivalued levels of brightness rather than randomness of those levels. In Chapter 6, a new set of fuzzifiers, contrast intensification operator "INT" and deenhancement operator "DEN" have been proposed and implemented [141-143]. The operators "INT" and "DEN" were implemented by using both sinusoidal and logarithmic transformation functions proposed in Chapter 4 and 5. Pal and King's [48-54] method is strengthened by this concept. This new concept using fuzzy set may be considered to be more realistic and compatible to the natural process.

Significant features of RED process have been elaborated in Chapter 7 by specifying some of the application areas. The RED process not only improves the contrast but also has applications, as envisaged now, in the area of picture transmission, coding, interpolation and edge crispening. Simulation of picture transmission [144] has been carried out by RED process using small experimental image. Interpolation problem has been tried out using RED process. Problem of edge crispening [140] has produced various edge accentuated results which are more subjectively pleasing and contains enough details at the background.

Conclusion and future scope of the work has been presented in Chapter 8. Results have been produced with small experimental image. It can be applied on various types of digital images. Implementation of the RED process is simple, fast and powerful. By this reversible process, the generalisation of the enhancement technique has been further strengthened by encompassing the problem which is difficult to be solved by irreversible enhancement process. The effort is simple, but the results are encouraging.