Fuzzy logics and soft computing techniques for noise reduction

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ABSTRACT

The aim of noise reduction is to extract the desired signal from its noise-corrupted version, using the proposed neuro-fuzzy system (NFS) as an adaptive filter. Noise reduction is the process of removing noise from a signal. All recording devices, both analog and digital, have traits that make them susceptible to noise. Noise can be random or white noise with no coherence, or coherent noise introduced by the device's mechanism or processing algorithms. Digital images are mostly corrupted by mixed noise from several sources. It is a challenging problem to remove mixed noise in color images. Generally, some image denoising filters can reduce either additive or impulse noise, but it fails to remove both impulsive noise and additive noise.

Keywords: Fuzzy system, Processing algorithm, Digital images

1. INTRODUCTION

The principal source of noise in digital images arises during image acquisition (digitization) or transmission. The performance of imaging sensors is affected by a variety of factors, such as the environmental conditions during image acquisition, and by the quality of the sensing elements themselves. For instance, in acquiring images with a camera, light levels and sensor temperature are major factors affecting the amount of noise in the resulting image. Images are also corrupted during transmission principally due to interference in the channel used for transmission.

A major portion of information received by a human from the environment is visual. Hence, processing visual information by computer has been drawing a very significant attention of the researchers over the last few decades. The process of receiving and analyzing visual information by the human species is referred to as sight, perception or understanding. Similarly, the process of receiving and analyzing visual information from a digital computer is called digital image processing [1].

Basic Image Processing: The term digital image processing refers to the processing of a two-dimensional picture by a digital computer. In other words, it implies digital processing of any two-dimensional data. A digital image is an array of real or complex numbers represented by a finite number of bits.

An image given in the form of a transparency, slide, photograph, and chart is first digitized and stored as a matrix of binary digits in computer memory. The digitized image can then be processed on a high-resolution television monitor. For display, the image is stored in a rapid access buffer memory which refreshes the monitor at 30 frames per second to produce a visibly continuous display.

General Applications: Image processing has a broad spectrum of application such as remote sensing via satellites and other spacecrafts, image transmission, and storage for business applications, medical processing, radar, sonar and acoustic image processing and robotics.

2. SAMPLING

i. Rectangular sampling - In most cases, images are sampled by laying a rectangular grid over an image as illustrated in Figure 1. This results in the type of sampling shown in Figure 2 and Figure 3.

ii. Hexagonal sampling - An alternative sampling scheme is termed hexagonal sampling.

Both sampling schemes have been studied extensively and both represent a possible periodic tiling of the continuous image space. We consider rectangular sampling, due to hardware and software considerations.
Local operations produce an output pixel value \( b[m, n] \) based upon the pixel values in the neighborhood of \( a[m, n] \). Some of the most common neighborhoods are the 4-connected neighborhood and the 8-connected neighborhood in the case of rectangular sampling and the 6-connected neighborhood in the case of hexagonal sampling illustrated in the figure.

![Fig. 1: Rectangular sampling (4 connected)](image1)

![Fig. 2: Rectangular sampling (8 connected)](image2)

![Fig. 3: Hexagonal (6 connected)](image3)

Converting from a continuous image \( a(x, y) \) to its digital representation \( b[m, n] \) requires the process of sampling. In the ideal sampling system \( a(x, y) \) is multiplied by an ideal 2D impulse train:

\[
b_{\text{ideal}}[m, n] = a(x, y) \sum_{n=-\infty}^{\infty} \sum_{m=-\infty}^{\infty} \delta(x-mX_0, y-nY_0) = \sum_{n=-\infty}^{\infty} \sum_{m=-\infty}^{\infty} a(mX_0, nY_0) \delta(x-mX_0, y-nY_0)
\]

3. TYPES OF OPERATIONS

- Geometric transformations such as enlargement, reduction, and rotation
- Color corrections such as brightness and contrast adjustments, quantization, or conversion to a different color space
- Digital compositing or Optical compositing (combination of two or more images)
- Recovery of a full image from a raw image format
- Image editing (e.g., to increase the quality of a digital image)
- Image registration (alignment of two or more images), differencing and morphing
- Image segmentation

3.1 Image Reconstruction from Projections

It is a special class of image restoration problems where two-dimensional objects are reconstructed from several one-dimensional projections. Each projection is obtained by projecting a parallel X-ray beam through the object. Planar projections are thus obtained by viewing the object from many different angles. Reconstruction algorithms derive an image of a thin axial slice of the object giving an inside view otherwise unobtainable without performing extensive surgery. Such techniques are important in medical imaging, astronomy, radar imaging geological exploration and non-destructive testing of assemblies.

3.2 Fuzzy Logic

Fuzzy logic was first introduced in 1965 as a new way to represent vagueness in everyday life [2, 3]. The definition of fuzzy logic as a superset of conventional (Boolean) logic that has been extended to handle the concept of partial truth values between "completely true" and "completely false". By this definition, fuzzy logic departs from classical two-valued set logic. It uses soft linguistic system variables and a continuous range of true values in the interval \([0, 1]\), rather than strict binary values. It is basically a multivalued logic that allows intermediate values to be defined between conventional evaluations like yes/no or true/false, etc. Notions like rather warm or pretty cold can be formulated mathematically and processed by computers."

3.3 Fuzzy Operation

FL requires some numerical parameters in order to operate such as what is considered significant error and significant rate-of-change of error, but exact values of these numbers are usually not critical unless very responsive performance is required in which case empirical tuning would determine them. [4]
For example, a simple temperature control system could use a single temperature feedback sensor whose data is subtracted from the command signal to compute "error" and then time-differentiated to yield the error slope or rate-of-change-of-error, hereafter called "error-dot". The error might have units of degrees F and a small error considered to be 2F while a large error is 5F. The "error-dot" might then have units of degree/min with a small error-dot being 5F/min and a large one being 15F/min. These values don't have to be symmetrical and can be "tweaked" once the system is operating in order to optimize performance. Generally, FL is so forgiving that the system will probably work the first time without any tweaking.

4. METHODOLOGY

The two common types of noise in images are impulse (or salt and pepper) noise and random (or Gaussian) noise. Impulse noise can be expressed by noise density. Random noise can be expressed in terms of its mean and variance values. [5] Noise can be generated during image capture, transmission, storage, as well as during image copying, scanning, and display. For examples, impulse noise can be generated through TV broadcasting and due to information losses; and random noise can be generated during film exposure and development.

A Monochrome (grayscale) digital image ‘O’ is often represented by a two-dimensional array where an address (i, j) defines a position in ‘O’, called a pixel or picture element. In a grayscale (or gray level) image, the only colors are shades of gray. A “gray” color is one in which the red, green, and blue components all have equal intensity in the RGB space, so it is only necessary to specify one single intensity value for each pixel, as opposed to the three intensities needed to specify a pixel in a full-color image. Often, the (grayscale) intensity is stored as an 8-bit integer giving 256 possible different shades of gray going from black to white, which can be represented as a [0,255] integer interval. In this interval, we consider several integer values \( p_1, p_2, \ldots, p_n \) with \( p_k \neq p_i \) and \( n \leq 255 \). If \( O(i,j) \) denotes the pixel value of the (two-dimensional) image ‘O’ at position \((i,j)\), then we can model the occurrence of impulse noise for a grayscale image, as

\[
A(i,j) = \begin{cases} 
O(i,j) & \text{with probability } p_i \\
p_1 & \text{with probability } p_1 \\
p_2 & \text{with probability } p_2 \\
\vdots & \text{with probability } p_2 \\
p_n & \text{with probability } p_n 
\end{cases}
\]

5. CONCLUSION

Development of parallel algorithms can also be done to counter-attack the computational overhead. In this paper, we have used fuzzy logic for noise detection. The investigation may be carried out to use a neural network for detection of noisy pixels in the image and fuzzy logic to remove the detected noise from the image. The work in this paper primarily focuses on impulsive& Gaussian noise suppression from images. [6] A new two-step filter (FIDRM), which uses a fuzzy detection and an iterative filtering algorithm, has been presented. This filter is specially developed for reducing all kinds of impulse noise (not only salt and pepper noise). Its main feature is that it leaves the pixels which are noise-free unchanged. In this paper, we have used fuzzy logic for noise detection. The investigation may be carried out to use a neural network for detection of noisy pixels in the image and fuzzy logic to remove the detected noise from the image.

6. REFERENCES


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