Computers and Electrical Engineering 000 (2017) 1–15

Contents lists available at ScienceDirect

Computers and Electrical Engineering

journal homepage: www.elsevier.com/locate/compeleceng

An adaptive decision based kriging interpolation algorithm for the removal of high density salt and pepper noise in images[☆]

R. Varatharajan[a,*], K. Vasanth[b], M. Gunasekaran[c], M. Priyan[c], X.Z. Gao[d]

[a] Associate Professor, Department of Electronics and communication engineering, Sri ramanujar engineering college, Chennai, INDIA
[b] Professor, Department of Electronics and communication engineering Vidya Jyothi Institute of Technology, Hyderabad, INDIA
[c] School of information technology and engineering, VIT University, Vellore, INDIA
[d] Lappeenranta University of Technology, Lappeenranta, Finland

ARTICLE INFO

Article history:
Received 29 December 2016
Revised 22 May 2017
Accepted 31 May 2017
Available online xxx

Keywords:
Kriging interpolation
Salt and pepper noise
Semi variance
Edge preservation

ABSTRACT

An adaptive decision based kriging interpolation technique for the removal of high density salt and pepper noise in images is proposed. The algorithm isolates the non noisy pixels and process only noisy pixel. The corrupted pixel is replaced by a value that is interpolated using the weights calculated using semi-variance between the corrupted pixels and the non noisy pixels in a confined neighborhood. The proposed technique requires at least three non noisy pixels in a current processing window, failing which the window increases adaptively. The proposed technique was found to exhibit good of quantitative evaluation and visual quality. The proposed algorithm also preserves image information with accurate noise detection when compared to many standard and existing algorithms.

1. Introduction

Salt and pepper noise (SPN) generally gets induced in images due to faulty camera sensors, Transmission errors, and mismatch in timing errors in A/D conversion. The conventional method for the elimination of noise in images is done using filters. Linear filters were good in eliminating salt and pepper noise but fail to preserve edges. But the information content of the image is preserved for non linear filters [1]. According to the filter theory for images a smaller window does not contain sufficient information for the noise removal on the converse a larger window is good in eliminating salt and pepper noise but blurs the image. Hence proper trade off has to be taken in choosing window size before developing an efficient algorithms for noise removal. Median filters are a class of non linear filters was found good in salt and pepper noise removal. The main drawback of the filter is that it replaces the entire pixel of an image with median value of the neighborhood irrespective of the pixel is noisy or not [2]. Weighted median filter [3] and center weighted median filter [4] treated few pixels inside the confined neighborhood with weights. Later median was evaluated based on the weights. Progressive switching median filter [5] detects the outliers and corrects only the corrupted pixel. Hence only the portion of the image pixels was filtered. The performance of the filter diminished with increasing noise densities [5]. Robust estimation statistics such as Lorentz estimator [7,8] were employed for identifying and correcting salt and pepper noise and mixed noise [6].

☆ Reviews processed and recommended for publication to the Editor-in-Chief by Guest Editor Dr. S. A. Aljawarneh.

* Corresponding author.
E-mail addresses: varathu8684@gmail.com, varathu21@yahoo.com (R. Varatharajan), vasanthecek@gmail.com (K. Vasanth), gunavit@gmail.com (M. Gunasekaran), priyanit085@gmil.com (M. Priyan), xiao.z.gao@gmail.com (X.Z. Gao).

http://dx.doi.org/10.1016/j.compeleceng.2017.05.035
0045-7906/

Many adaptive, two stage, iterative algorithms [6–12] were proposed for better noise removal at high noise densities. But the performances of the algorithms were found bad at high noise densities or increasing window size blurs the images. Decision based median filter (DBA) [13] identified the corrupted pixel using max-min detector and even checked for noisy median and subsequently replaced preprocessed neighbor. At high noise densities this replacement resulted in streaking effect. The effect was minimized using an Improved Decision based median filter (IDBA) [14] which used the mean of preprocessed pixels. A class of Decision based unsymmetrical trimmed filters was introduced for the elimination of high density salt and pepper noise. These filters perform unsymmetrical elimination of SPN on the image data and replace the noisy pixels with unsymmetrical trimmed median [15,16] or Midpoint [17] or Variants [18]. Cascaded algorithms were proposed for high density salt and pepper noise that works in two stages. First stage filter was a decision based median filter and second stage was unsymmetrical trimmed median [20] or midpoint [19,20] or variants [21]. Interpolation techniques such as continued fractions [24], third and fourth order Bspline [22,23], ordinary Kriging [26] were used for the removal of salt and pepper noise. These algorithm works well at very high noise densities but blotching of regions or smearing of edges takes place at high noise densities. Ordinary kriging interpolation [26,27] estimated each non noisy pixel in the current processing window using ordinary kriging interpolation. If all the values are same then it prefers 3×3 windows. This filter also uses arbitrary window size. Adaptive weighted mean filter (AWMF) [31] was proposed to eliminate the errors that occur during filtering in AMF. The algorithm is a modified version of weighted trimmed mean. The size of the window reaches till 39. Over the study it was observed that either the filters do not remove SPN noise effectively or do not fair properly at high noise densities or induce ambiguity(blotching, smearing, fading, streaking) while elimination. Hence a suitable algorithm has to be formulated for the removal of high density salt and pepper noise without inducing ambiguity. The paper is briefed as follows. The Section 2 deals with theory behind Kriging interpolation for salt and pepper noise removal techniques, the proposed Adaptive decision based Kriging interpolation filter (ADKIF) and its methodology of the interpolation technique. Section 5 briefs the simulation results and discussions involved with the proposed algorithm. Section 6 deals with the conclusion of the proposed algorithm.

2. Interpolation for salt and pepper noise removal

Over the years the interpolation techniques were used for image processing operations such as zooming, impainting, warping etc., until now recently these interpolation techniques were used in salt and pepper noise removal. Interpolation for noise removal refers to estimating a new pixel at a corrupted location from uncorrupted pixels in small vicinity. Renowned interpolation algorithms (Radial basis function, triangulation, splines etc.,) estimate the pixel at a given pixel location as weighted sum of pixel values in a closer vicinity. Generally all the interpolation discussed above use weights as per the functions that give a lesser weight for increasing distance between pixels. The investigation in this paper is based on Kriging interpolation based on semivariogram for the estimation of salt and pepper noise.

2.1. Kriging interpolation

Kriging is the most powerful statistical interpolation method. This interpolation is linear, since the interpolated values are weighted linear combinations of available uncorrupted pixels in a closed neighborhood. This interpolation is unbiased since the mean of all error is equal to zero. This interpolation tries to minimize the variance of errors. Hence kriging is referred as optimal interpolation. Kriging interpolation uses a weight as per the pixel weighting function instead of an arbitrary function. In Kriging, a semivariogram is developed which gives the spatial difference in the neighborhood of uncorrupted pixels. The mathematical model of the semivariogram is used for the calculation of weights at different corrupted pixel locations. Hence calculation of Semivariogram is an important step in Kriging interpolation [25]. This method is governed by variance of non noisy pixel in the current processing window rather than using a piecewise polynomial function that optimize smoothness of the estimated value.

2.2. Theory of interpolation using semivariogram in kringing interpolation

The kriging interpolation mainly use expected squared prediction error based on stochastic model. Consider the spatially occupying samples located at ix locations is assumed as the realization K(i1) of the random variable K. Considering a space Q where the number of pixels is dispersed, realizations of the random variable K(i1),K(i2)……K(iL), having similarities between them.

Hypothesis of stationary model is also related to second central moment (variance) instead of mean is given by the similarity between the two random variables that will depend on the spatial distance that separates the variable and independent of its location, Where $\upsilon(h)$ represents the semivariogram of two samples, h gives the squared Euclidian distance between two samples observed, K(i1), K(i2) represents the observed samples assumed as random variable.i1 and 12 are two locations of the observed data as specified in Eqs. (1) and (2).

$$\upsilon(\mathrm{h}) = \upsilon(\mathrm{K(i1)}, \mathrm{K(i2)}) = \upsilon(\mathrm{K(ix)}, \mathrm{K(ix+h)}) \quad (1)$$

$$\mathrm{h(i1, i2)} = (\mathrm{ix}, \mathrm{ix+h}) \quad (2)$$

Please cite this article as: R. Varatharajan et al., An adaptive decision based kriging interpolation algorithm for the removal of high density salt and pepper noise in images, Computers and Electrical Engineering (2017), http://dx.doi.org/10.1016/j.compeleceng.2017.05.035