Characterization of Noise removal based on Hypergraph model of Images

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Abstract
The quality of the image plays a vital role in image processing technique. It can be determined by the removal of the noisy pixels in the images. In this paper, we designed the hypergraph model for the representation of images. We use noise removal algorithm for digital images.This algorithm is based on the hypergraph model of images. This is used to detect the noisy pixels and thus can be removed by using Root Mean Square (RMS) approximation. The identified noisy pixels are denoised and improved the quality of images. The PSNR and MAE are used to measure the performance of the model.Then this system is used to compare the different noisy images and also we characterize the hypergraph parameters.

Keywords—Hypergraph, Image Neighborhood Hypergraph, Impulse noise, Intesity level, Neighborhood relation, Root Mean Square.

I. INTRODUCTION

Nowadays, noise removal and segmentation are major challenges in image processing applications. Image processing is rapindly growing area of computer science. It involves processing and altering an existing image in a desired manner. The relations between data are represented by binary relations. The appropriate mathematical tools to model these relations are graphs. Graphs are very powerful tools for describing many problems and structures in image processing and pattern recognition. But graphs only describe some binary relations and are not always sufficient for modeling some complex problems or data. So we propose Hypergraph model for images.

Hypergraph theory, originally developed by C. Berge in 1960, is a generalization of graph theory. A hypergraph is a graph in which an edge can connect more than two vertices. This concept can model more general types of relations than binary relations. To any digital image, a hypergraph, the Image Neighborhood Hypergraph can be associated and used for image processing. There are several literatures have proposed the image representation based on hypergraph, and it is proved to be a powerful tool to use in some applications of image processing.

Digital Images play a vital role in daily life applications such as Satellite television, magnetic resonance imaging and also in areas of research such as geometrical information systems, Astronomy and Mathematical morphology. Images are often contaminated by factors such as channel transmission error, impulse noise from noisy sensors. Since smoothening a region will destroy image details (for instance, edges), while sharpening may lead to unwanted intensification of noise, attenuation of noise and preservation of details are usually two conflicting aspects of image processing. Thus image enhancement through noise reduction (also called image cleaning) is a fundamental problem in image processing. Depending upon the type of imagery and goals of restoration various noise reduction techniques make various assumptions and so one technique is not useful for all applications [1]. Several filtering techniques have been reported to literature over the years for various applications [2–8]. However, these schemes do have limitations as most of them are based on statistical approaches rather than syntactical considerations such as fixation of threshold for distance and intensity levels.

To overcome these difficulties and in order to provide a more viable tool for processing images by taking into account the topological and geometrical aspects of an image, Bretto [2] has proposed a hypergraph model. The effective algorithms proposed by his research group in acquiring image details through segmentation, edge detection, and noise removal process pave way for future research in the applications of hypergraph in image processing. Several attempts have been made by researchers to remove various types of noises such as Salt and Pepper (SP), random valued noise, impulse noise (gray values to lie between 0 and 255), additive Gaussian noise and uniform noise. Noise removal algorithms described by Bretto and other researchers have been extensively studied.

II. LITERATURE SURVEY

HYPERGRPH MODEL OF DIGITAL IMAGE:

A hypergraph H is a couple (X, ε) consisting of a non-empty finite set X together with a family $\varepsilon = (Ei)i2J$ of non-empty subsets of X called hyperedges [5], with $\cup Ei = X$, $i \in J$, where $J = \{1, 2, \ldots, n\}$, $n \in N$.

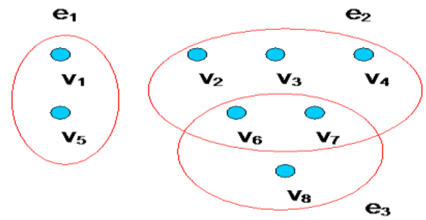

Fig. 2.1. Hypergraph

Fig. 2.1 shows an example hypergraph with 8 vertices and 3 hyperedges. V = {v1, v2, v3, v4, v5, v6, v7, v8}, E = {e1, e2, e3} ={{v1, v2}, {v2, v3, v4, v6, v7}, {v6, v7, v8}}.

NOISE REMOVAL:

Generally, images are often contaminated by mixture of Gaussian and impulse noises due to the imperfection of camera sensors and communication channels, faulty memory locations in hardware, etc.

Salt and pepper noise is a form of noise typically seen on images. It represents itself as randomly occurring white and black pixels.

Gaussian noise is statistical noise that has its probability density function equal to that of the normal distribution, which is also known as the Gaussian distribution.

The median filter is a nonlinear digital filtering technique, often used to remove noise. Such noise reduction is a typical pre-processing step to improve the results of later processing (for example, edge detection on an image). Median filtering is very widely used in digital image processing because, under certain conditions, it preserves edges while removing noise.

The wiener filter removes the additive noise and inverts the blurring simultaneously. The wiener filtering is optimal in terms of the mean square error.

Mean filter, or average filter is windowed filter of linear class, that smoothes image. The filter works as low-pass one. The basic idea behind filter is for any element of the image take an average across its neighborhood.

The filters like Robert, Sobel, Prewitt are used to remove the Gaussian noises(white and random). Log operator are greatly used in detecting the edges even in the noisy environment. The mean filter preserves the edges during the noise removal process. The major limitations of these kinds of filters are they increases noise sensitivity if correct location of edge is increased, removes too much details in image with edge sharpness.

The filters like Median, Centre weighted median (CWM), Switching median (SM) are more effective to remove the fixed valued impulsive noise (Gray values either 0 or 255) there by preserving the general details of image while denoising. But, it tends to modify both the noisy and noise free pixels.

The filters like adaptive CWM, SM, Two pass median, Pixel-wise median of absolute deviation from median, Progressive switching median and Median rational hybrid filter are very much effective in removing the random valued impulse noises and used to restore the noisy image corrupted by RV noise. But, the selection of the adaptive threshold becomes a major problem in denoising.

The filters like Prewitt and Kinsen detectors, Zero crossing edge detector with Laplace operator and Gaussian edge detector are very handy in removing both the random and fixed valued impulse noises, because they utilize the 2nd order pixel derivatives and it is also based on differential operator. It is mainly used to find the edge in impulsive noise environment. But it is highly sensitive to noise and often yields inaccurate results.

The peak and valley filter is used to remove the uniform noises; the recursive maximum–minimum method replaces the noisy pixel with a value based on neighborhood information. It is significantly less in accuracy. The fuzzy based filters are greatly used to remove the mixed noises; since it's processed on the higher order noise components the delay time is prolonged.

III. PROPOSED ARCHITECTURE

We propose an efficient noise removal technique in images. The architecture of our framework is shown in Fig. 3.1.

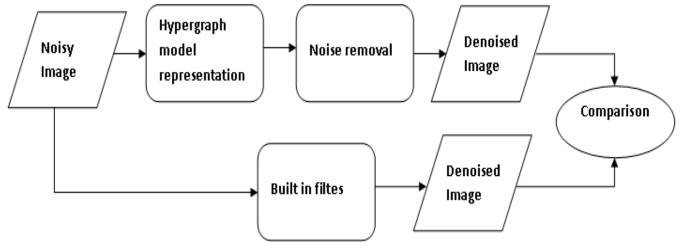

Fig. 3.1. System Architecture

One of the first major step of this project is Hypergraph representation of images. We identify the hyperedges using neighbourhood relations. Then we use Helly property [4] to detect the isolated stars in the image. The identified noisy pixels are denoised through Root Mean Square (RMS) approximation. Finally, we get the denoised images then we compare with traditional filters. The performance of our algorithm is based on PSNR and MAE.

HYPERGRAPH MODEL REPRESENTATION:

➢ **Step 1 Input Image** (I)

A digital image is representated by a function

$$\mathbf{I : (X \subseteq Z^2) \rightarrow (C \subseteq Z)}$$

X - locality of Pixel
C - Intensity of Pixel

Domain Distance Metric - d (chess board);
Intensity Distance Metric – t (Euclidean)**;**

A grid is a loop less regular graph, associated with a regular lattice which may be triangular or square or hexagonal. Most commonly used grids in image processing are 4-connected grids and 8-connected grids defined on a square lattice of R^2. Fig. 3.2.a and b show representations of 4- and 8-neighbours of a point,respectively.

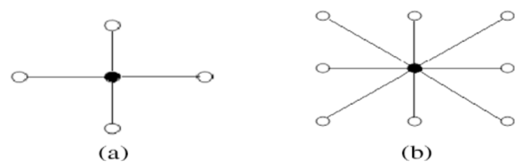

Fig. 3.2. (a) 4 – neighbors of a point.
(b) 8 – neighbors of a point.

The 4- and 8-connected neighborhood system use the following distance metrics, respectively, where a = (x1, y1) and b = (x2, y2):

d(a, b) = |x1 _ x2| + |y1 _ y2|
(Chessboard distance metric)

d∞(a, b) = max{|x1 - x2|, |y1 - y2|}
(City block distance metric)

➢ **Step 2 Distance** measure d and d' on C and X give rise to neighborhood relation on the image

$$\forall_x \in X, \Gamma_{\alpha,\beta}(x) = \{y \in X : y \neq x, d[I(x), I(y)] < \alpha \text{ and } d'(x, y) < \beta\}$$

d' on X defines a grid with chess board distance metrics,
d defines the difference in intensity value
α is intensity threshold and
β is neighbourhood size.

Neighborhood Hypergraph:

A graph G, the hyper graph having the vertices of G as vertices and the neighborhood of these vertices as hyper edges (including these vertices) is called the neighborhood hyper graph of G.

➢ **Step 3 Construction** of image neighborhood hypergraph $H_{\alpha,\beta}$ on I

$$\mathbf{H}_{\alpha,\beta} = (X, (\{x\} \cup \Gamma_{\alpha,\beta}(x))_{x} \in X)$$

X denote vertex set
x is vertices and
$\Gamma_{\alpha,\beta}$ is neighbourhood relation.

➢ **Step 4 Finding Hyperedges of $E_{\alpha,\beta}(x)$**

$$E_{\alpha,\beta}(x) = (\{x\} \cup \Gamma_{\alpha,\beta}(x), x \in X)$$

The image is first represented as the set of union of hyperedges. As for the hyperedges themselves, these are determined by two Image Neighborhood Hypergraph (INHG) parameters, with the concept of 8-bit neighborhood and INHG of a graph being central.

NOISE REMOVAL:

Hyperedges have been identified from the noisy image. Now we should identify isolated stars using Helly property. Next we should detect noisy hyperedges and apply filter in that, which is shown in Fig. 3.3. Finally we get the denoised image.

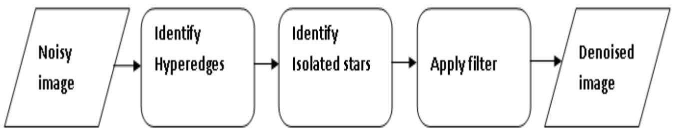

Fig. 3.3. Noise removal

➢ **Step 1 Detection of Noisy Hyperedges**

A hypergraph has the Helly if each family of pair-wise intersecting hyperedges has a non-empty intersection(that is they belongs to a star).

a. Check if cardinality of $\mathbf{E}_{\alpha,\beta}(\mathbf{x}) = \mathbf{1}$ else
b. Check for isolated hyperedge

$\forall_j \in J, j \neq i$, **if** $E_i \cap E_j \neq \emptyset$, **then** $Ej \subset Ei$

$E_{\alpha,\beta}(x)$ is a noisy hyper edge if it satisfies any one of two conditions:

(1) The cardinalilty of $E_{\alpha,\beta}(x)$ is equal to 1: $E_{\alpha,\beta}(x)$ is not contained in any of successive hyperedges which are pair-wise disconnected.

(2) When $E_{\alpha,\beta}(x)$ is an isolated hyper edge, there exists y belonging to open neighborhood of $E_{\alpha,\beta}(x)$ on the grid such that $E_{\alpha,\beta}(y)$ is isolated.

➢ **Step 2 RMS approximation**

An image restored using a RMS approximation is given by the expression

$$f(x,y) = \sqrt{\left(\frac{1}{mn}\sum_{s,t}\left(g(s,t)\right)^2\right)} \qquad (s,t) \in S_{X,Y}$$

Where g(s,t) denotes the gray value of the pixel at (s,t).

Hypergraph based Root Mean square approximation (HGRMS)

- To make INHG more adaptive
- INHG is flexible enough to accommodate RMS approximation for ensuring better clearance of the noises.
- Image details are preserved accurately by detecting the noisy pixels using INHG parameters & denoising only the affected pixels.

IV. PERFORMANCE MEASURE

Evaluation of Image quality metrics

- Peak Signal to noise ratio (PSNR)
- Mean absolute error (MAE)

Peak Signal to noise ratio:

The PSNR is most commonly used as a measure of quality of restored images.

$$PSNR = 10\log_{10}\frac{255^2}{\frac{1}{mn}\Sigma(r_{ij}-x_{ij})^2}$$

Mean absolute error:

The mean absolute error is one of a number of ways of comparing forecasts with their eventual outcomes. The MAE measures the average magnitude of the errors in a set of forecasts, without considering their direction. It measures accuracy for continuous variables. The MAE is the average over the verification sample of the absolute values of the differences between forecast and the corresponding observation. The MAE is a linear score which means that all the individual differences are weighted equally in the average.

$$MAE = \frac{1}{mn}\sum_{ij}(|r_{ij}-x_{ij}|)$$

Where r_{ij} and x_{ij} denote the pixel values of the restored image and original image respectively.

V. EXPERIMENTAL RESULTS

Fig. 5.1(a) shows the Lena image of 256×256 size. We applied our algorithm to this image. Fig. 5.1(b) shows the image with 10% salt & pepper noise.

Fig. 5.1(a) Original image

Fig. 5.1(b) Image with 10% Salt & pepper noise

The hyperedges are found from the noisy image using two hypergraph parameters α and β. We found the optimal value of this parameters empirically. Then isolated stars have been identified using Helly property. Noisy hyperedges have been detected. The identified noisy pixels are denoised through Root mean square(RMS) approximation. Various values for the hypergraph parameters are used for experimentation. Finally we got the optimized values α=20 and β=2.

Fig. 5.1(c) shows the denoised image for the image shown in Fig. 5.1(b). Our algorithm could able to remove almost all the noise. The performance is analyzed using two measures PSNR and MAE.

Fig. 5.1(c) Denoised image

PERFORMANCE ANALYSIS:

The image has been contaminated by Salt & pepper noise with various noise ratio for PSNR and MAE. The HGRMS is compared with various built-in filters namely Median filter, Wiener filter and Average filter. HGRMS is outperforms all the other filters.

Table 1

Results in PSNR for the Lena image at various noise levels (Salt & pepper noise) for different filters.

Noise Ratio (%)	Median Filter (MF)	Wiener Filter (WF)	Average Filter (AF)	Hypergraph based Root Mean Square (HGRMS)
5	36.26	33.11	31.44	40.33
10	35.98	31.06	30.56	37.41
15	35.16	29.83	29.97	35.18

Table 2

Results in MAE for the Lena image at various noise levels (Salt & pepper noise) for different filters.

Noise Ratio (%)	Median Filter (MF)	Wiener Filter (WF)	Average Filter (AF)	Hypergraph based Root Mean Square (HGRMS)
5	1.76	4.78	5.28	1.04
10	1.92	6.87	6.35	1.72
15	2.41	8.73	7.38	2.33

Fig. 5.2(a) and (b) shows the results in PSNR and MAE for the Lena image at various noise levels (Salt & pepper noise) for various filters namely Median filter(MF), Wiener filter(WF), Average filter(AF) and Hypergraph based Root mean square(HGRMS).

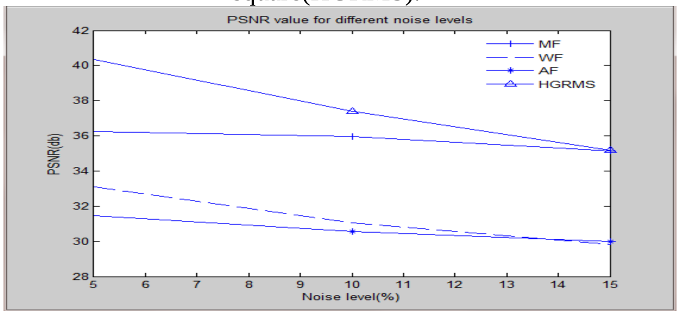

Fig. 5.2(a) Results in PSNR for the Lena image at various noise levels (Salt & pepper noise) for various filters: MF,WF,AF and HG based RMS.

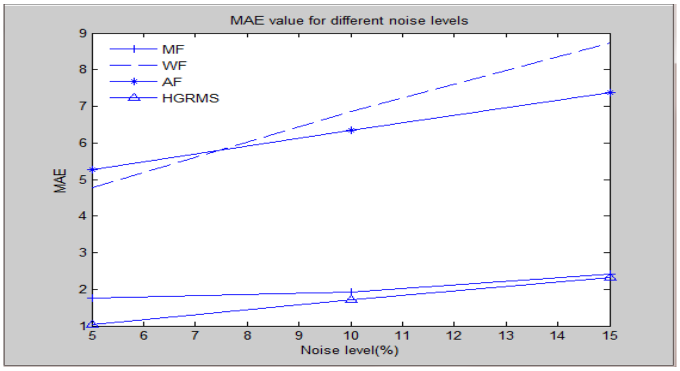

Fig. 5.2(b) Results in MAE for the Lena image at various noise levels (Salt & pepper noise) for various filters: MF,WF,AF and HG based RMS.

Fig. 5.3(a) Original image

Fig. 5.3(a) shows the house image of 512×512 size. We applied our algorithm to this image. Fig. 5.3(b) shows the image with 10% salt & pepper noise. Fig. 5.3(c) shows the result of our algorithm on Fig.5.3(b).

Fig. 5.3(b) Image with 10% Salt & pepper noise

Fig. 5.3(c) Denoised image

Table 3 shows the performance of our algorithm to various standard images.

Table 3

Results of HGRMS Algorithm for Standard images from [11].10% Salt & pepper noise, α = 20 and β = 2

S.No	Image	Standard	PSNR	MAE
1	Girl	256×256	35.49	2.44
2	House	512×512	37.58	1.71
3	Jelly beans	256×256	41.52	0.75
4	Moon surface	256×256	35.72	2.39
5	Lena	256×256	37.41	1.72

VI. CONCLUSION

Hypergraph-based image representation is used to remove the noises. The experimental result shows that we could able to reconstruct perfectly. Hypergraph-based image representation can be used for low-level treatment and gives better results. Such representation is not limited to segmentation, edge detection and noise cancellation.

Two extensions of HG model are planned. One is noise removal for color images. The other plan is segmentation based on hypergraph model of images.

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