Original Article

Blind Image Quality Assessment with Image Denoising: A Survey

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Abstract

The quality of an image is most important at every stage of its processing. Images captured with recent smart devices such as digital cameras or smart mobile phones can be affected by various types of noise, which degrades image quality. The evaluation and elimination of noise or distortion in a picture is viewed as significant as, the evaluation of the image's quality. This study presents a survey of available techniques and algorithms for denoising images and determining image quality. This paper studies the types of noise or distortions, techniques, parameters used by the algorithm, various metrics used to assess the quality and the performance of the algorithm. Some of the important filters, databases in the area of image quality assessment and denoising are discussed in this paper.

Index Terms: IQA (Image Quality Assessment), Image Denoising, Quality Assessment Metrics, Denoising Filters.

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INTRODUCTION

Nowadays images are captured from many devices such as cameras, mobile phones etc. Images play a vital role in our day-to-day life. In particular some images are used in some sensitive fields of operations such as space, mission, hospital etc. In these fields the quality of an image is an important factor for processing the images. This quality of an image is affected by various de-noising factors like Environmental factors, Low light and sensor temperature, Dust particles in the scanner, Transmission channel interference etc. Figure 1 takes an image as input, denoises it and provides the image quality assessment of the denoised image. Figure 2 receives an image as input, assess the quality of an image and then provides the denoised image. In this paper a detailed analysis of various techniques used in image quality assessment with denoising techniques to remove the distortion present in the image is studied.

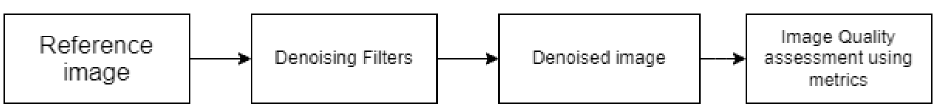

Fig. 1. IQA after denoising

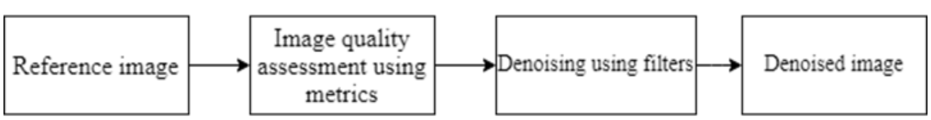

Fig. 2. IQA before denoising

In image processing, denoising of an image is considered as the key pre-processing step. The production of noise while capturing pictures by camera or other imaging devices is removed by denoising methods in order to enhance image visual quality. Image quality is a significant value for service-oriented processing of image which provides further processing enhancement such as compression, segmentation and classification accuracy. This paper focuses on a compact review of estimations, methodology used for removal of noise from the image. This paper additionally focuses and reads up significant measurements and metrics utilized for image quality appraisal.

Image quality can be evaluated simply by displaying it to an expert human evaluator. This is the most efficient technique to assess the visual quality of the digital images and this is known as subjective image quality assessment. The evaluation is different for each individual so we can take assessment from multiple evaluators but it is a very tedious process. As a result, an automated system for evaluating and assessing image quality is required. "Objective Image quality assessment" refers to the process of estimating an image's quality using a machine. There are three types of image quality assessment such as,

Full reference image quality assessment (FR-IQA)

Reduced reference image quality assessment (RR-IQA)

No reference image quality assessment (NR-IQA).

Where, in FR-IQA reference image is fully available, in RR-IQA reference image is available with partial information's and in NR-IQA no reference image is available. We provide more attention to the no reference images in our study which will be useful for the researchers. The remainder of this work is presented in the following sequence. The methods for assessing image quality are examined in Sec. II. With denoising of the image based on the domains of the filters used in the denoising. In Sec. III, various results of the survey taken and the discussion are provided and in Sec. IV. Conclusions are given.

DOMAIN BASED DENOISING OF IMAGE WITH BIQA

Basically, there are two types of images denoising approaches [23] such as,

i) Spatial domain

ii) Transform domain

Spatial domain is of two types such as linear filters and non-linear filters. Linear filters are also named as average filters and it is of two types: mean filter and wiener filter. Linear filters degrade image details and edge information's which results in blurring of the image. Nonlinear filter is developed to overcome disadvantages of linear filter. The simplest nonlinear filter is the median filter. Filtering approach in transfer domain depends upon choice of basis function. Non-data adaptive and data adaptive filters are two types of Transform domain. Further classification and details of the domain are given in figure 3.

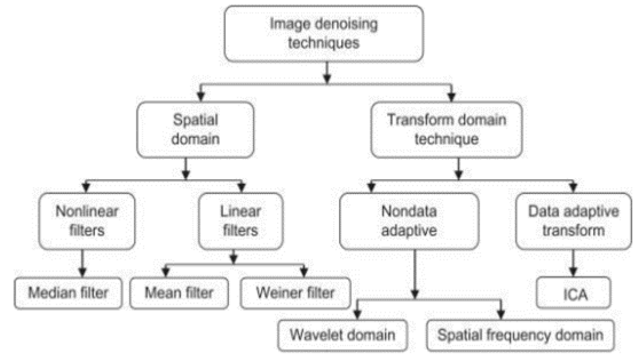

Fig. 3. Classification of various image denoising domain

Spatial Domain based Denoising with BIQA

Xin Li, in his paper [1], addresses the difficulty in assessing the image quality without any reference. For denoising the image, a mean curvature [2] based denoising algorithm is used in additive white gaussian noise. The amount of energy filtered when the iterative filtering method converges is measured to find the noise level in the image. The experiment done in this paper shows accurate noise level. The author proposes least square based optimal detection strategy. To reduce noise in Least square (LS) estimation, median filter is used. The combination of the idea proposed in this paper provides accurate quality assessment of an image which is better than peak signal-to-noise ratio (PSNR). But still a method to handle the difference between image features and noise levels is not addressed by the author.

Priyanka Srivastava et al. [5] proposed a performance assessment model for an image to overcome the challenge in preserving the image details during filtering of noisy image process. The proposed method concentrates on the consequences of error, edge and structural image filtration deterioration [6]. This paper employs the noise removal with details preservation and also the quality evaluation of filtered image [7]. The proposed filter's performance is estimated using the parameter (P filt), which gives an image's quality. For the provided distortions, P filt is determined as the average value of the PSNR (i.e., error, edge and structural distortions). More than PSNR, the proposed model correlates strongly with the Structural Similarity Index (ssim) and fidelity metrics. This method is ideal for evaluating the performance of denoising filters.

Mingchen Jia and Mingming Dong [16] discusses about various noises present in the image and filters used for denoising the image [15]. The author also analyses the optimal metric to assess the quality of an image. Mean, median, Weiner and wavelet filtering are deployed in this paper. Metrics like mean square error, PSNR, structural similarity index method are analyzed and best denoised image is found. The paper proposes an objective evaluation model to inference the image which is processed and get an optimal solution. Experiment results shows that wiener and wavelet filtering provide better denoising of an image.

While choosing the filter the block size is also important. The metric used in this paper for quality assessment after denoising is useful for quality evaluation and de-noising of an image.

Fabrizio Russo [25], proposes a novel vector method that provides accurate measurements of quality of an image. The proposed method exploits spatial and amplitude information about a filtered pixel to analyse whether the pixel is affected by actual noise or distortion. The proposed method performs better than other metrics for images corrupted by gaussian noise. In this method, gaussian noise is added and denoised with bilateral filter [7] and mean filter for experiments. The new proposed vector method with Root mean squared error (RMSE) metrics provides correct measures. The proposed method overcomes all the limitations caused by previous methods because of a classification algorithm, both spatial and amplitude information about a filtered pixel and an autocalibration procedure which is effective.

Jianjun Li et al [28], addresses the challenges security and authorization of an image faces, which are purely dependent on quality of an image. The author proposes a unique IQA method which is based on dual convolutional neural network structure. This method is trained with gray and colour human visual system and applied to parameter selection of denoising algorithm [29]. To reduce the number of iterations during training, the model is embedded in Rudin–Osher–Fatemi (ROF) model in search of optimal parameters. This achieved best denoising effects. The paper proposes an algorithm cascading no reference image quality assessment technique [30] and denoising image technique based on Convolutional neural network (CNN) and visual saliency. This technique uses weighting image blocks to assess the images quality. The Spearman rank order correlation coefficient (SROCC) value of the developed algorithm is high compared to other algorithms. The method is trained both in LIVE [8] and TId2008 databases.

Si Lu [31] proposed a no-reference image denoising quality assessment technique that may be used to choose the best denoising algorithm with the best parameter settings. This technique gives you complete control over the quality evaluation procedure, allowing you to automatically modify the parameter settings of a denoising algorithm to achieve the best possible denoising results. The study establishes a big denoising benchmark that may be shared with all research communities. Block-matching and 3D filtering (BM3D) generates the denoising results with various parameter values. The image is denoised using additive white Gaussian noise, Poisson noise, and Salt & Pepper noise. The experimental findings show that the parameter setting is effective and efficient, and that it is extremely close to the genuine ideal as determined by the Ground Truth (GT) PSNR/SSIM.

Transform Domain based Denoising with BIQA

Haoyi Liang and Daniel S. Weller addresses the difficulty faced when multiple distorted images are available [9]. They proposed a comparison-based image quality assessment technique(C-IQA) with denoising algorithm selection framework. It selects the reconstruction parameter by comparing with different recreated images and different parameters. This method can be effectively used in large datasets as it removes the problem of selecting optimal denoising algorithm. Experiment results shows that selecting from different denoising algorithm provides more stable and better denoising performance. Six state-of-the-art denoising algorithms such as BM3D, INL, Texture, WESNR, PGPD, PCLR are used in this paper for comparison-based image quality assessment [10].

Rostyslav Tsekhmystro et al. considers initial and intermediate image quality assessment [12] stages of a noisy image. The paper proposes a benchmark for image processing under noisy condition with concentration in three integrated parts such as image quality assessment, prediction of image visual quality for full reference metrics and denoising with prior processing. This benchmark is hosted on a web platform, with capabilities available to users with a variety of device types and operating systems. The proposed method has low computational complications, so it can be used in large datasets. It also outperforms faster than other modern denoising algorithms. The author implemented the technique in web platform using Web Assembly and TensorFlow.js technologies.

Karen Egiazarian et al. concentrates on images having low contrast and noise like surface [14]. Denoising of such images is challenging as it results in loss of image details or smoothing. The paper proposes modified matrix splitting domain decomposition method (MSDDM) metric which provides large SROCC value between many quality metrics. The best denoising method should not exceed 0.5 db of PSNR metric. With this small difference we cannot analyze which denoising methos is optimal. Proposed MSDDM metric is based on maps with dissimilarity and works with non-predictable energy of image areas. It employs BM3D [15] filter with different threshold value. The proposed dissimilarity index provides better performance compared to other metrics. The author also provides a new test image dataset which has 75 denoised reference images and 300 filtered images. This can be used for other research purpose also.

Andrey Rubel and Vladimir Lukin [22] examined image quality assessment methods as well as the efficacy of denoising algorithms [17]. The author concludes the prediction accuracy is still low and image quality assessment (IQA) for denoising is still not solved fully. Though the quality metric has been improved due to filtering, denoising does not improve visual quality of an image. Denoising techniques such as Discrete cosine transform (DCT) filter [24] and BM3D are taken for analyse and the Spearman rank order correlation coefficient (SROCC) value does not exceed 0.7. The proposed analyse results shows that SROCC values for IQA such as dipIQ, BLINDS-II with DCT filter for denoising shows good results. For BLIINDS-II, LPSI and SSEQ BM3D filter gives good SROCC values. Though new parameters are added in proposed system, the performance does not improve.

Fabrizio Russo [26] concentrates on the loss of details of an image due to noises such as residual noise and collateral distortion. A new approach to investigate the accuracy of wavelet-based image denoising is presented. This paper describes "residual noise and collateral distortion can be directly derived from wavelet denoising theory regardless of the specific choice of wavelet function. Results shows how exact evaluations of important features can be computed without being impaired by limitations and inaccuracies of current metrics".

Xiangfei Kong, and Qingxiong Yang [27], proposed two new non reference image quality metrics such as Non-Reference Structure Similarity measure (NRSS) and No-Reference Patch Matching measure (NRPM). This can be taken as state of art image denoising algorithms for automatically de-noising. Both the metrics are evaluated on LIVE2 and TID2013 [13] datasets using standard Spearman and Kendall rank-order correlation coefficients (SROCC). The experimental results shows that it outperforms all other metrics. Non-Reference Structure Similarity measure NRSS is used to measure the denoised images quality. This can be applied to a parametric denoising algorithm. No-Reference Patch Matching measure NRPM is an IQA metric directly measures the noisy image measures needed for denoising. The NRSS measurements for noise reduction and structure preservation are done by SSIM metric. Other state-of-the-art non-reference metrics for image auto denoising are less robust to low-level or high-level noises than the proposed metric in this study.

Chen Zhang et al. [32] proposed a novel method for human vision and image recovery which is named as corrupted reference IQA (CR-IQA) [4]. FR-IQA scores of denoised images with correspondence to CR-IQA is agreed when simulation is done. The proposed metric describes the similarity between processed image and real image, and it achieves its maximum with the ideal reference image, but it may also be computed without it. The measure correctly predicts the whole reference image quality assessment scores of SSIM, W-SSIM, VIF, and VSNR using the statistical equivalences of AWGN/Poisson distributions. CR-IQA may be utilized to create FR-IQA-optimal denoising parameters, and CR-IQA delivers more desirable denoising outputs that are more compatible with perceived image quality than NR-IQA, according to the results. One area where future research could be addressed is the computational cost.

Wavelet Domain based Denoising with BIQA

Chen Zhang and Keigo Hirakawa [3] analyses the challenge in increased noise of an image due to miniaturization of dimensions which reduces photon count. They aim to develop objective visual quality metric which predicts the quality of an image in an unsupervised manner for the intensity image recon-structed from Poisson counts. As a result, corrupted reference quality assessment (CR-QA) is proposed. This metric describes similarity of processed and ideal reference image. With ideal reference, it also reaches a maximum. The metric can also be computed without the need of an ideal reference image. The experiment of CR-QA on Structural similarity index shows that proposed optimal Poisson image denoising performs better than MSE optimal denoising.CR-SSim metric is proposed which is more accurate for real images.

Samarth Bharadwaj et al. [11] presents a solution for performance degradation of denoising algorithms due to noise, blur, adverse illumination etc. A quality enrichment-based framework is proposed which selects the parameter for image denoising. If correct parameter is found, the denoising algorithm is more efficient. This paper uses support vector machine (SVM) to discover the association between quality of an image evaluation scores and the best parameter for noise removal algorithm. The paper deploys wavelet based soft thresholding technique known bayes shrink for denoising. Both in terms of ac-curacy and computational time, the suggested model improves performance.

Network Domain based Denoising with BIQA

Biju Venkadath et al. addresses the problem of optimizing classical denoising algorithm due to complex loss functions [18]. The paper proposed deep convolutional neural network based denoising and deep CNN based quality assessment of an image [19,20]. Quality assessment CNN(QA-CNN) predicts the image quality using average precision of the input image. The quality measured is the amount of distortion in the denoised image. By computing appropriate gradients, the deep CNN-based denoising approach improves the output of the QA CNN with loss function and weight updates. Other denoised images appear to be finer than the proposed denoised image.QA CNN also outperforms other algorithms by showing its generality. By cascading denoising CNN with QA CNN improves the performance of image retrieval. Proposed framework deploys pre-trained convolutional layers of VGG-16 CNN. Using Adam optimizer [21], the denoising CNN is trained independently on each dataset at each noise level. The proposed work can be extended for any enhancement of images operations.

Results and Discussion

In the previous sections, a comprehensive review of the literature in models for BIQA with denoising of the image has been discussed. An overview of discussed images and noise added for distortion is provided in Table 1. Most of the noise added are gaussian noise which means the noises that mimic the effect of many random processes that occur in nature. Also, majority of the images are converted into gray-scale in pre-processing step. The filter used for removing noise, number of filters used and the domain of each filter is given in Table 1. Most of the domains are transform domain and minimum one filter is used. It is analyzed from the literature that BM3D outperforms all other filters. Table 1 also gives the details about the metric used in image quality assessment. All of the techniques are tested on a variety of datasets, the majority of which feature contain images distorted by at least one sort of distortion. The dataset details are provided in Table 1.

Table. 1. Various parameters discussed in BIQA based denoising algorithms

Ref.	**Type of image**	**Noise added**	**Denoising domain**	**No of filters**	**Denoising filters**	**IQA metric**	**Dataset**
[1]	Jpeg	AWGN, impulse noise	Spatial	1	Anisotropic diffusion filter- mean curvature based denoising	PSNR	Leena
[3]	Linear Gray Scale	Poisson	Wavelet	1	bivariate Skellam thresholding	SSIM	Mc Gill Calibrated image dataset
[5]	Jpeg	Impulse, Gaussian, Speckle	Spatial	7	Median, averaging, Weiner-sliding window, bilateral, guassian, anisotropic	PSNR, P_FILT	Woman hat image
[9]	Jpeg	Gaussian, mixed, Speckle	Transform	4	BM3D, PGPD, Texture, PCLR	SSIM	LIVE, CSIQ dataset
[11]	Jpeg	Gaussian, Poisson, speckle, salt& pepper	Wavelet	1	Bayes shrink	SVM	AR face dataset
[12]	Jpeg	Awgn	Transform	1	DCT	SSIM4, PSNR	RANDOM IMAGE
[14]	Gray Scale	Awgn	Transform	1	BM3D	MSDDM	FLT database
[16]	-	Common, Gaussian	Spatial	4	Mean, median, weiner, wavelet	MSE, PSNR, SSIM	Woman with hat
[18]	Jpeg	Gaussian	Neural network	1	CNN	CNN	Oxford building dataset, Paris dataset
[22]	Grayscale	AWGN	Transform	2	DCT, BM3D	SROCC	Subjective IQA Database
[25]	Grayscale	Gaussian	Spatial	1	mean	IQA metric	Dataset
[26]	-	Residual	Transform	2	Wavelet transform based filter, BM3D	VECTOR	Barbara, Light house, Boats image
[27]	Jpeg	-	Transform		BM3D	RMSE	Simulated brain web data,Shepp-Logan phantom image, Boats image, Airfield image
[28]	Grayscale	Gaussian	Spatial-morphology based	1	ROF	NRSS, SSIM, NRPM	Tid 2013, LIVE 2, SUN
[31]	Jpeg	Gaussian, Poisson, salt & pepper	Spatial, transform	7	Gaussian, bilateral, median, NCM, Geodesic, DCT, BM3d	SROCC, PSNR, SSIM, FSIM, LCC	LIVE
[32]	-	Gaussian, Poisson	Transform	1	BM3D	PSNR, SSIM, RMSE, RSE	Flicker

CONCLUSION

In the absence of a reference image, assessing the quality of a distorted image is a more difficult process that demands more intellect. The impact of noise on photographs, as well as the filters used for denoising, must be considered while developing a better image quality assessment system. Removal of noise in the image before assessing the quality of the image provides better results in pre-processing of images. Designing of such a system is challenging as human knowledge, observation and inference is not an easy task to model mathematically. The methodologies utilized, the type of distortion, metrics calculated filters, and benchmarked datasets are all examined in this research. The sorts of degraded photos in the datasets, as well as the dataset's major uses for quality assessment with denoising, are summarized. This survey is expected to offer prospective researchers with a comprehensive review of available algorithms for evaluating the quality of a denoised image.

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