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A Novel Curvelet Based Image Denoising Technique For QR Codes

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Abstract

Abstract— Image denoising has been one of the most comprehensive research areas in image processing. Several image filtering and denoising applications has been proposed in various literature that offers generalized to application specific solution for noise removal from the images. Computer generated graphics images has different properties than the natural protographs in a sense that the CG images has different resolution at different scales whereas natural photographs maintains their aspect ratio at all the scales. Hence conventional wavelet transform results in poor performance for such images. In this work we have proposed a novel Curvelet based technique to denoise QR codes. We show that proposed Curvelet based technique results in better decoding of the code at higher noise level in comparison to that of the wavelet based denoising.

***Index Terms*—QR Code, Curvelet Transform, Wavelet Transform, Image Denoising, Image Filtering**

I. INTRODUCTION

QR codes are extremely popular binary code to represent data through images. Information such as phone numbers, Email IDs are represented through QR codes. These codes are printed on T-Shirts, mugs and other objects. There are several mobile applications available that allows decoding of these information through a photograph of the object. User can wear a T-Shirt with a QR code that carries his information during a presentation. Audience can easily acquire this information by taking a photograph of the user and then decoding the information through their mobile apps.

Figure 1 shows some possible and popular use of QR codes. Conventional image

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Figure 1: Probable use of QR Codes

As such photographs are prone to be noise affected due to environmental, and light conditions. Also printed images on shirts and cups are prone to get noise affected during washing and cleaning process respectively. Conventional image filtering techniques fails to remove such noises due to particular properties of these images. QR codes (like many other computer generated imaging systems) are scale sensitive. For instance a QR code generated for 300X300 dimensions will not be decoded when resized to 256x256.

Most of the existing image denoising technique including wavelets depends upon basis function. A basis function is a mathematical function that can be used to generate the image. Filtering techniques understands noise figure by comparing the basis function of the image and corresponding noise image.

Wavelet is an extremely popular means of analyzing noise figure as it represents a multi scale basis function for the images. The parameters are selected in such a way that the aspect ratio remains same for all the scales. However as we have already discussed, QR codes, being computer generated images needs a different approach.

Therefore it is extremely important to design new image filtering paradigms for such computer generated images.

Therefore in this paper we present a novel curvelet transform based image denoising technique for QR codes.

I. RELATED WORK

Digital images play an important role in daily life applications such as satellite television, computer generated images, photographed image and so on . Data Sets collected by image sensors are generally contaminated by noise[1][2].

Noise is a distribution (like Gaussian) of unrelated information over image. Rank proposed a technique for quantitative analysis of image degradation through noise variance analysis[3]. Buades[4] studies various imaging denoising techniques which are mainly divided into two types: Local based filtering and Global filtering. Non local algorithms are applied on image blocks and are most popular. Weiner filter is one of the most popular local image filtering technique. Another popular and effective local image filter is median filter. S Kumar[5] has presented a significant comparison of weiner and Median filters which presents a very good basis for understanding non local filters.

Cheng[6] has presented wavelet based Image denoising technique. Rahman[7] has combined Median filter with wavelet to present effective image filtering technique. Kajubek[8] on the other hand combined wavelet with Weiner filter to obtain very good image filtering result.

Starck[9] presented basic idea of Curvelet based filtering for image denoising.

Wavelets are generalization of Fourier transform in a sense that they represent the information about both location as well as spatial frequency. Curvelet transforms evolves from wavelet transform but differs from wavelet transforms which are directional in nature in a sense that the degree of localisation in orientation varies with scale. As this is an inherent property of computer generated images like QR codes, the method is most suited for QR code denoising technique.

Image denoising is a fundamental problem in the field of image processing that deals with detecting the uncorrelated information distribution and separating them from the actual information.

Here the curvelet transform was used for this problem. Candes and Donoho developed a new multiscale transform, [5],[9] which they called the curvelet transform. The transform was designed to represent edges and other singularities along curves much more efficiently than traditional transform. The developing theory of curvelet will obtain dramatically smaller asymptotic mean square error of reconstruction and recovering images which are smooth away from edges better than wavelet methods.

Though QR code has become one of the most popular visual watermarking techniques, it lags extensive research in filtering. Zhou[10] proposed a technique for image filtering for the QR code.

Due to lack of sufficient research in this direction, we have selected proposed technique for QR filtering. As curvelet represents best basis function for representing such images, we choose curvelet transform. Another important property of curvelet transform is that the filtering results in smoother edges then any other techniques.

The method is presented in detail in next section.

II. METHODOLOGY

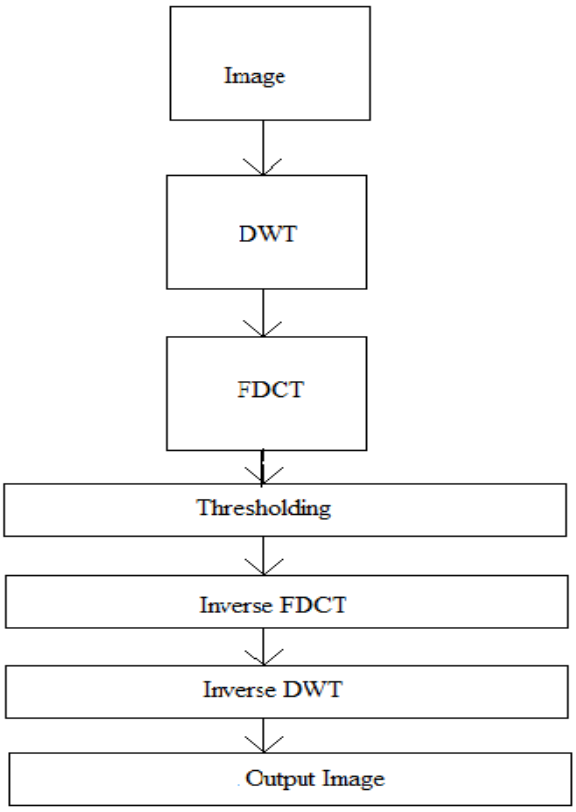

Figure 2: Proposed Methodology

Firstly we compute the norm of curvelet transform where curvelet coefficients are normalized using equation (1)

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$$c^{D,N}(j,\ell,k) = \frac{n}{\sqrt{L_{1,j}L_{2,j}}} c^{D}(j,\ell,k), \qquad (1)$$

Where L1,j ,L2,j are parallelogram side lengths. Now the objective is to detect the noisy pixels. This is done through a thresholding technique that compares local statistical properties of the given noisy image with that of generated image from the basis function. Arithmatic mean of the distorted QR image is calculated. This is the center value of all the neighboring pixels. Spatial frequency measure (SFM) is calculated that represents the distorted image.

Now the threshold is calculated as:

Threshold =(DOP(DI)*SFM(DI)* mean(DI))

+ (mean(DI) *(s = n))

Where

DOP is the Difference Operator.

Mean is the arithmetic mean.

SFM is the Spatial Frequency measurement.

DI is the distorted image.

n is the number of coefficient of the curvelets.

s is the number of iteration

Now Fast Discrete Curvelet transform is applied on the noisy images using equation (2)

$$c^{D}(j,\ell,k) = \sum_{n_1,n_2 \in P_j} \hat{f}[n_1, n_2 - n_1 \tan\theta_\ell]\, \tilde{U}_j[n_1,n_2]\, e^{i2\pi(k_1 n_1/L_{1,j} + k_2 n_2/L_{2,j})}, \qquad (2)$$

FDCT is directly obtained from FFT by estimating the coefficients of curvelet . Now the calculated threshold is applied on the FDCT of noisy image and resultant FDCT matrix is converted to spatial domain image using inverse treansform.

It is important to notice that the entire process depends upon number of curveelt coefficients. We present a novel technique of calculating the optimum number of coefficients. We use a step learning process with a known image and it's distorted image. We start with minimum number of coefficient and filter the image with proposed technique. The process is repeated with more number of coefficients. Then the PSNR is compared with previous one. The process is stopped

when current PSNR is lower than the previous. Therefore we select optimum coefficients intelligently which results in better filter performance.

We consider db5 based wavelet transform as db family wavelets have been extensively being suggested by literatures.

III. Results and Discussions

We used online tool [11]for generating QR code. We introduced noise through program in Matlab and recovered the image using both wavelet as well as curvelet filters. We then give both noisy and denoised image as input to another online tool for QR code decoding and decoded the code. [12] is used for online decoder. We then compared the successful decoding of QR code.

We present the result of a QR code for following text:

"KCT College Of Engineering

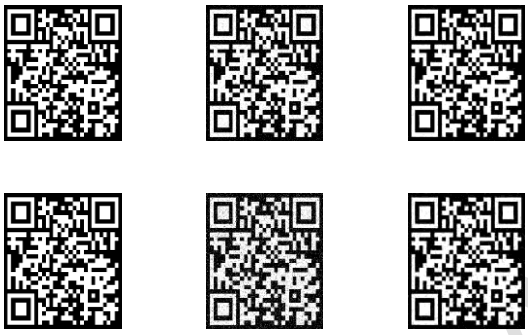
Gulbarga"

The corresponding image is as shown in following figure.

Figure 3: QR Code for the selected text paragraph.

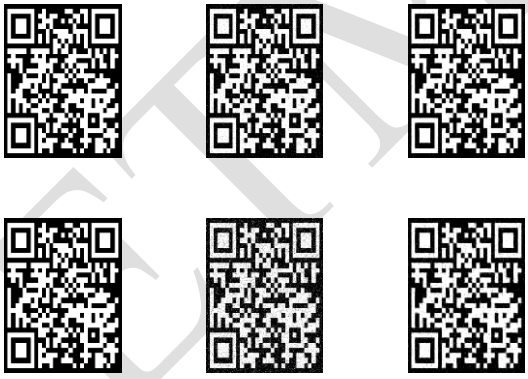
This image is subjected to noise analysis and denoising. QR codes have embedded error correction code and therefore can correct low errors bellow 25% without any filtering techniques. However under high percentage of noise, edges and white areas gets distorted which results in poor decoding. Figure 3 and Figure 4 presents the actual image (a), noisy image (b) and

error corrected image(c) for 25% and 50% noise (row 1 and row 2 respectively) for wavelet based technique and proposed technique respectively.



(a) *(b)* *(c)*

Figure 4 :Wavelet based filtering: at 25% and 50% Noise



(a) *(b)* *(c)*

Figure 5: Proposed Curvelet Based Filtering

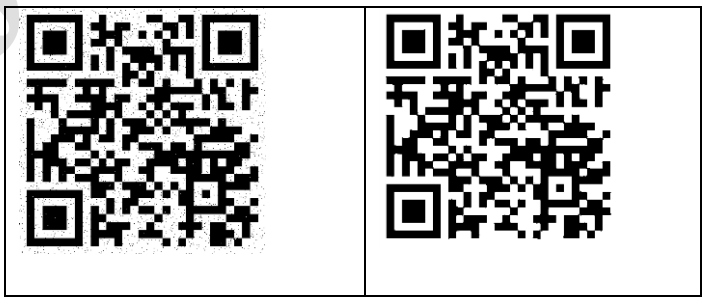


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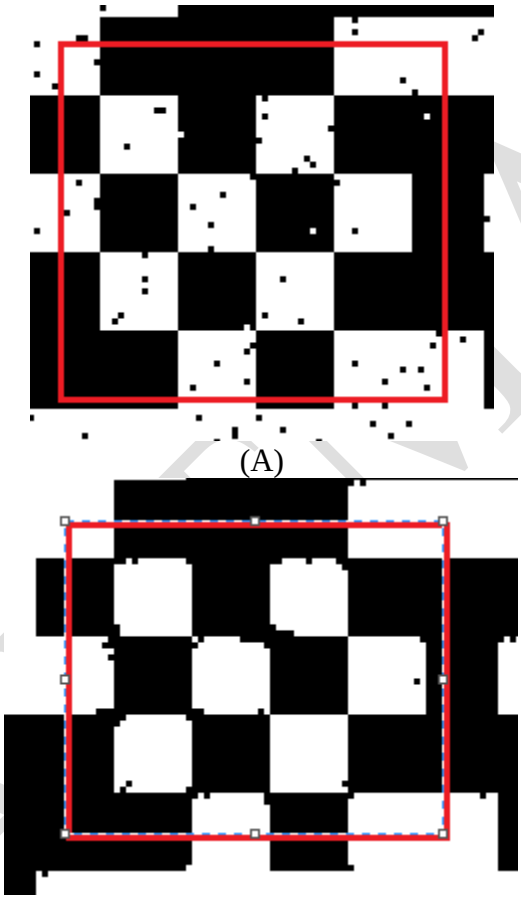
Figure 6: Noisy v/s Recovered Images for 50% Noise (Gaussian)
Figure 6 presents noisy and filtered images for 50% noise. We can clearly see that the proposed technique can recover the error better and retains the edge information.

It is important to understand the effect of noise in detail. Hence in figure 6, we zoomed same areas of images presented in figure 6 to show the noise effect and their filtering effect.



(A)

(B)

Figure 7: Noisy(A) and Corresponding Resulted Denoised QR Code(B) Zoomed

We can clearly see that the noisy image has too much noise and therefore it is not possible to decode it. However, QR code is much cleaner and therefore can be decoded easily.

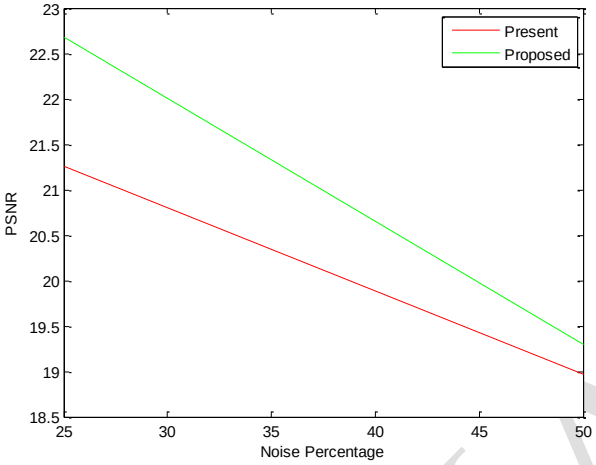


Figure 8: Performance analysis of the PSNR of Present And Proposed Systems for Salt and Pepper Noise

We can see the performance of the proposed Curvelet based system is better than the wavelet based filtering technique.

We performed the same experiment for Gaussian distribution with sigma=.5. Result is presented in figure 7.

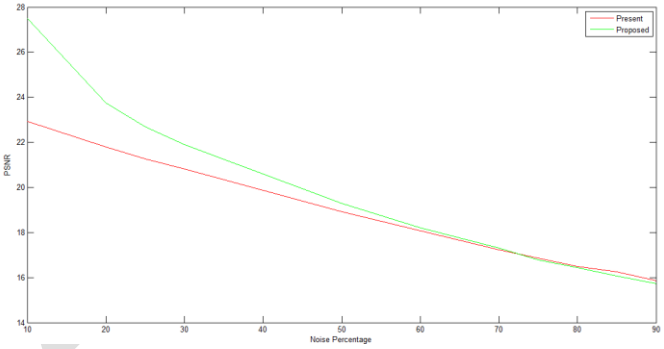
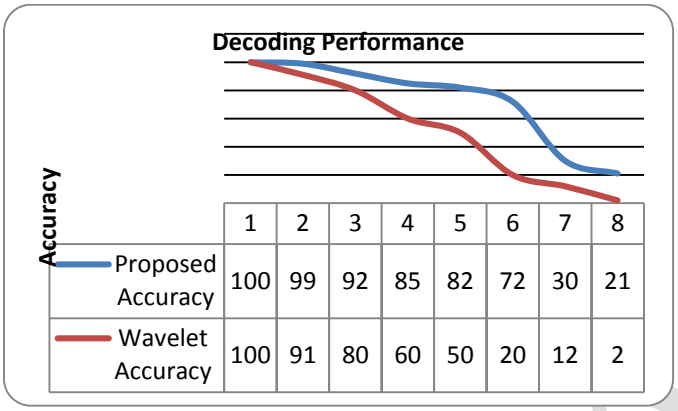


Figure 9: Analysis of Results for Gaussian noise

We can see that the proposed system performs better than wavelet transform.

Primary objective of QR code is to decode the underneath information. Hence mere quantitative analysis through PSNR is not sufficient to compare the techniques. We therefore run qualitative analysis. Same QR code at noise level was given as input to decoder and we checked the number of times the decoding is successful. For each noise level we noted down the success rate of both wavelet based technique and curvelet based techniques for ten readings and calculated the

percentage of successful decoding. Results are presented in Figure 8.



	1	2	3	4	5	6	7	8
Proposed Accuracy	100	99	92	85	82	72	30	21
Wavelet Accuracy	100	91	80	60	50	20	12	2

Figure 10: Performance comparision of proposed and wavelet based techniques in terms of decoding accuracy of filtered image

IV. CONCLUSION

Digital photographs are being part of our day to day life now. QR codes have gained significant importance over past few years and are now extensively used to represent important information like mobile numbers, email addresses in the form of visual watermark. There is no significant research in this direction. In this work we have proposed efficient technique for QR image denoising using Curvelet based technique. It is evident from the results that the proposed system can produce better decodable denoised image. Hence proposed technique can find wide application in QR based apps. However at high noises the performance of both are similar and quite low. This is due to the fact that both wavelet and curvelet represents basis functions of images which is formed with wrong parameters at higher noises. Learning based technique can be used to adjust the parameters for improving the performance of the proposed system.

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