



Investigating the Extent of Noise in Digital Images using Singular Value Decomposition

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Abstract: Digital images have an inherent amount of noise introduced either by the imaging process or manual creation. Singular value decomposition (SVD) is one of the most important and useful factorizations in linear algebra. We describe how SVD is applied to problems involving image processing—in particular, how SVD removes the noise from digital images using linear calculations. In this paper, we proposed an efficient model of noise removal. Further the results have been compared with that of existing noise removal median filter to investigate the extent of removal of unwanted noise from digital images.

Keywords: Filtering, Median filtering, Noise removal, Singular Value Decomposition, Singular Values.

I. Introduction

Digital distribution introduces a flexible and cost effective business model that is beneficial to multimedia commerce transaction. Digital imaging has demonstrated its worth in a variety of fields from education to medicine. Although theories are quickly becoming realities in today's technological society, the range of possibilities for digital imaging is wide open. An increased flexibility in getting better quality images to the readers will tempt editors, photographers and other to manipulate photographs [1]. The digital nature also allows individuals to manipulate, duplicate or access media beyond the conditions agreed upon for a given transaction. With some powerful software one can remove or replace some features in a digital image without any detectable trace. These kinds of operations are regarded as tampering. Tampering also includes the addition of different noise. Noise is an unwanted data applied to the image to disturb its basic feature and results in false information to the society. These altered or noisy digital images affect the authenticity and integrity of the digital image content and therefore it is essential to identify the original image [2]. For medical, military and judicial applications such operations are not allowed. Under these conditions authentication has become an important issue to ensure trustworthiness of digital images in sensitive application area such as government, finance, health care and judiciary. There is no such method which can handle all the manipulations of the tampered image. Recently researchers have focused on SVD based models. Singular Value Decomposition is one of the robust and efficient methods to produce noise free digital images [3].

II. SINGULAR VALUE DECOMPOSITION (SVD)

There is no such method which can handle all the manipulations of the tampered image. Recently researchers have focused on SVD based models. SVD is based on a theorem from linear algebra which says that a rectangular matrix A can be broken down into the product of three matrices - an orthogonal matrix U, a diagonal matrix S, and the transpose of an orthogonal matrix V. The theorem is usually presented something like this:

$$A_{mn} = U_{mm} S_{mn} V_{nn}^T$$

where $U^T U = I$; $V^T V = I$; the columns of U are orthonormal eigenvectors of $A A^T$, the columns of V are orthonormal eigenvectors of $A^T A$, and S is a diagonal matrix containing the square roots of eigen values from U or V in descending order. SVD has many practical and theoretical values; special features of SVD are that it can

be performed on any real (m, n) matrix. In contrast to other methods of tampering detection, SVD is a robust technique which helps in detecting various alterations like scaling, rotation, orientation, noise etc. This technique involves refactoring of given digital image in three different feature based matrices. The small set called singular values preserves the useful features of the original image. The advantages of SVD include lesser memory requirement, insensitive to sampling, reduce noise, shape independence etc. It has many applications in data analysis, signal processing, pattern recognition, image compression, noise reduction, image blurring, face recognition, forensics, embedding watermarking to an image [4] [5]. The SVD can be used to restore a corrupted image by separating significant information from the noise in the image data set. In this study, an SVD based model is proposed for removing noise from digital image.

III. IMAGE FILTERING AND DENOISING TECHNIQUES

Different types of filtering operations are applied to the image set to detect and remove noise from digital images. In the following sections, we will discuss only median filter technique for noise removal. After that we compare the former existing median filtration process with that of proposed SVD based noise detection and removal model to study the extent of noise removal from different sets of digital images. First, we will discuss the types of noise that are used during the filtering process. As there are varieties of noise associated with the digital images but we focus on standard Salt and pepper noise for our experimental study. After applying the noise we use the existing median filtering method for noise detection and removal process.

IV. MEAN AND MEDIAN FILTERING

Very simple noise removal techniques that are widely used for comparing with other filtering methods include mean and Median filtering. Denoising is also a reconstruction process in images that is intended to remove values that represent the noise or “foreign objects”. Noise filtering techniques, such as mean and median filtering, have been used to restore corrupted image data. After applying particular noise and blur to images, we can compute the SVD of the image and apply an appropriate filtering method to obtain a restored signal. In Median filtering of noisy images, the value of the output pixels are determined by the Median of the neighborhood pixels within a defined mask. It is able to reduce pixel outliers without affecting the sharpness or the quality of the image. In mean filtering, the output pixels are set to an average of the pixel values in the neighborhood mask of the corresponding input pixels. The Median is much less sensitive than the Mean to pixel outliers. For this reason, Median filtering is considered a better approach than mean filtering for reducing noise in images. The following general steps were taken to experiment on filtering techniques in digital images:

1. Obtain a “clear” sample image.
2. Convolve the image with a PSF filter to introduce a blur (noise-free case) or apply zero-mean Gaussian noise.
3. Run the corrupted image through the filter.
4. Compare the processed image to the original image.

Using this median filtering technique, noise can be removed up to some extent from digital images. This experiment does not give satisfactory results. In this study, we design a robust SVD based noise removal model which gives appropriate results for given noise queries [6].

V. LITERATURE REVIEW

The altered digital images affect the completeness and integrity of the digital image content and therefore it is essential to identify the original image. Different researchers study various methods and techniques of detecting tampering in digital images. Various filtering techniques are under consideration which helps to detect different aspects of noise in digital tampered image. But there is no one method which can handle all the manipulations of the noisy image. We proposed a SVD based noise detection and removal model which gives good results in most of the areas. We studied different techniques of noise removal proposed by different researchers. Various methods investigate effective features and applications of SVD based noise removal model.

D.Sharma et.al discusses the image compression and a robust noise removal technique in digital images using Singular value decomposition [7]. A.Zehtabian et al. in his research study proposed non-destructive approach, in which the noisy signal is initially represented in a Hankel Matrix and then the SVD operator is applied on the matrix to divide the data into signal subspace and noise subspace. The results of applying the proposed method on different synthetic noisy signals indicate its better efficiency in noise reduction compared to the other time series methods. The obtained results also indicate that using the proposed approach keeps the main structure of the original signal unchanged [8].

Another SVD coherency-based technique that provides both signal enhancement and noise suppression is introduced by M. Bekara et al. It has been implemented in a variety of seismic applications—mostly on a global scale [9]. U. M. Gokhale et al. proposed a passive or blind technique for the tampering detection as it does not require a priori information or rely on pre-distribution watermarking or digital signature which is the case with active approaches. The tampering can be detected by comparing the PSNR and SNR of the authentic and tampered image. The region of tampering is localized using the blocks. The method identifies a tampered region when noise has been added locally. Random noise could be added across the entire image to conceal image tampering, and this would not be detected by this method [10].

SVD can be shown by T. Workalemahu to improve the appearance of distorted or noised images by implementing it in several filtering techniques. In SVD block denoising technique, a sample image matrix is divide into square blocks and SVD of each block is calculate to reduce the changes in singular values and singular vectors. Filtering noise is performed through eliminating changes in singular values and singular vectors that resulted from additive white Gaussian noise [6].

D. Muti, study an application of SVD based techniques for image and video filtering. In this case study different filters are designed by using SVD. The Truncated SVD method for image filtering is also presented [11].

Singular value decomposition (SVD) is one of the most important and useful factorizations in linear algebra. Y.-R. Kalnins et al. describes how SVD is applied to problems involving image processing—in particular, how SVD aids the calculation of so-called Eigen faces, which provide an efficient representation of facial images in face recognition. Although the Eigen face technique was developed for ordinary grayscale images, the technique is not limited to these images. Imagine an image where the different shades of gray convey the physical three dimensional structure of a face. Although the Eigen face technique can again be applied to show how SVD can be used to reconstruct three-dimensional objects from a two-dimensional video stream [12]. Simon Doclo et al. in this research study discussed a class of SVD-based signal enhancement procedures, which amount to a specific optimal filtering technique. A number of simple symmetry properties have been derived for the optimal filter. When this SVD-based optimal filtering technique is applied to multi-microphone noise reduction, it is

shown that it exhibits some kind of beam forming behavior and that it outperforms standard beam forming techniques [13].

VI. PROPOSED WORK

Multiple filtering techniques are applied to a variety of digital images in order to generate a noise free image. But these existing filters do not produce an accurate image corresponding to the original image. Therefore a robust SVD based noise detection and removal method is proposed which helps in generating efficient results for noise free image. The main goal of our research study is to produce an accurate noise free image which is approximately similar to the corresponding original image. Our proposed SVD based technique is applied to the given set of tampered images and results in desired digital images which shows the extent of noise removed from digital images. Also the comparative analysis is performed between the existing median filter and proposed SVD based noise removal model to investigate the best and efficient method for noise removal.

VII. METHODOLOGY

SVD based noise removal technique is applied to four different sets of digital images. These digital image sets comprises

Digital Image Sets					Salt and Pepper Noise	
Set1					N(0.1)	
Set2					N(0.2)	
Set3					N(0.3)	
Set4					N(0.4)	

Fig1. Digital Image Sets and different types of Standard Noise

of various geometrical shapes ranging from simpler to complex ones. With these three given input sets - Set-1, Set-2, Set3, Set-4 different experiments can be performed to justify our proposed model.

We considered three different types of salt and pepper noise, (mean < 0.5) N1, N2, N3 and N4 associated with different image sets for further processing. Salt and pepper noise is applied to different images in four images sets and then our proposed SVD based noise removal model is applied to noisy image. These different images sets are considered to investigate the efficiency and effectiveness of the proposed SVD based noise removal model. Image sets consists of simpler geometrical images so that the results can be easily calculated.

Fig.2 shows the schematic diagram of SVD based noise detection and removal model. A given image is normalized to the required format as per the requirement of the proposed model. Among the predefined noise, one noise is added to the given test image. After that the SVD is applied to preserve the basic features of digital image which is helpful for further processing. SVD based detector is applied to the noisy image to estimate the presence of noise in test image. After calculating the amount of noise present, SVD based noise removal method is imposed on the processed image in order to remove the maximum quantity of noise and generates an accurate noise free image corresponding with that of the original image. On the other hand, the existing median filtering technique is applied to the normalized image for noise removal. Once the noise gets removed, both the images (refined image by SVD based noise removal model and the filtered image by Median filter) are then compared with each other

to investigate the performance of results generated. The comparative analysis shows the extent of noise removal and the efficiency of the proposed SVD based noise removal model. Different experiments have been performed using different image from the four given image sets with that of appropriate noise addition. The basic pseudo code along with the corresponding flowchart of the proposed SVD based noise detection and removal model is discussed below to understand the proper functioning of the proposed work.

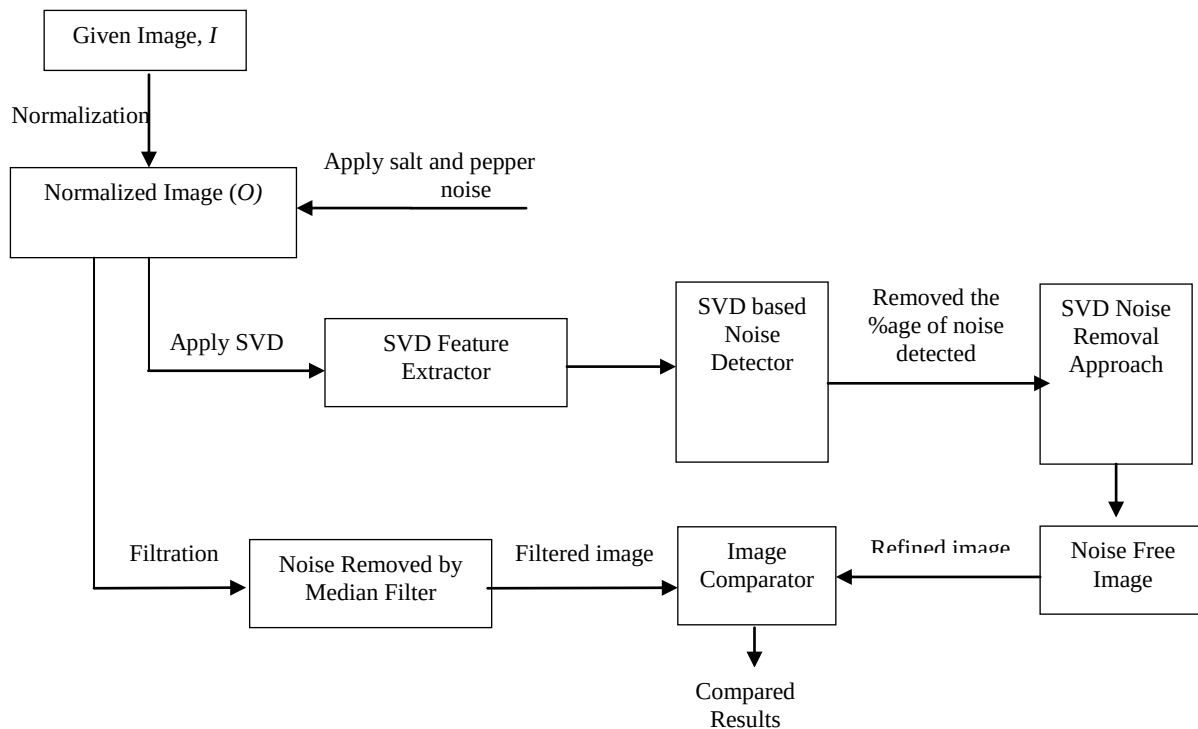


Fig2. Schematic diagram of proposed SVD based Noise Detection and Removal Method

1. Consider an image $I_{i(5*5)}$ from image set I_5 and then normalized in required format.

2. Add Salt and pepper noise, where mean < 0.5 ,

$$I_{i(SVD)} + N_i \rightarrow \sum (USV)^T (N_i * I_i),$$

3. Estimate noise $\sum ((g-g1) / g) / (n*m)$
 $i=1 \text{ to } 5$

Where $g, g1$ are singular values and n, m are the dimensions of image matrix

4. Noise removed

$$^A S_{i \ i=1 \text{ to } 5} = 0.3 * ^B S_i + 0.3 * ^C S_i + 0.414$$

Where S_i is the singular value, and A, B, C are different types of digital images. On the basis

The coefficients (a, b, c) of singular values S_i were normalized so as to obtain the maximum desired results. The calculated values are $a=0.3, b=0.3, c=0.414$.

Using the above pseudo code, noise can be estimated and removed accordingly. The flow of the proposed SVD based noise detection and removal model is shown in fig. 3.

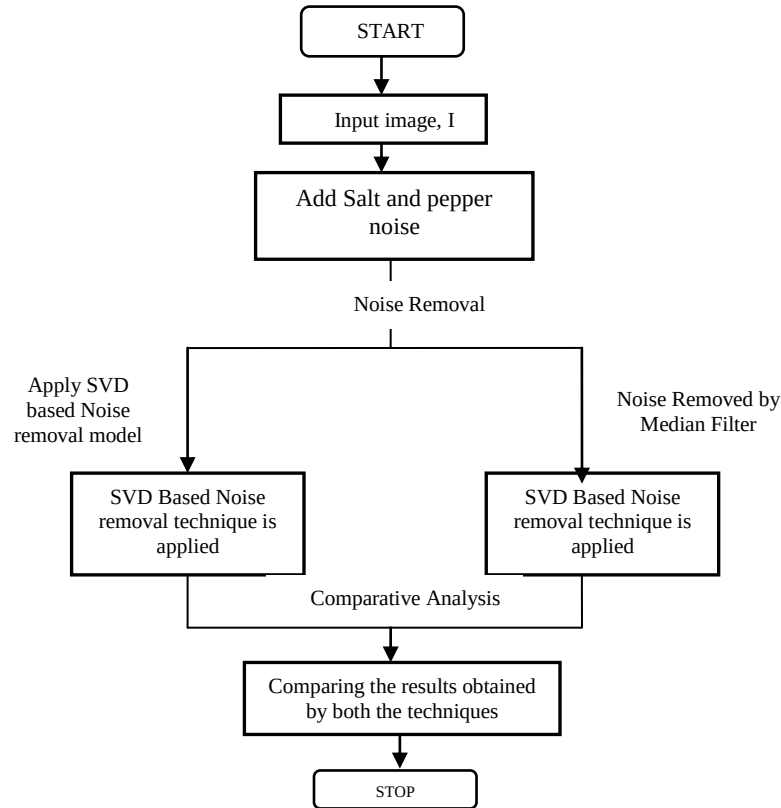


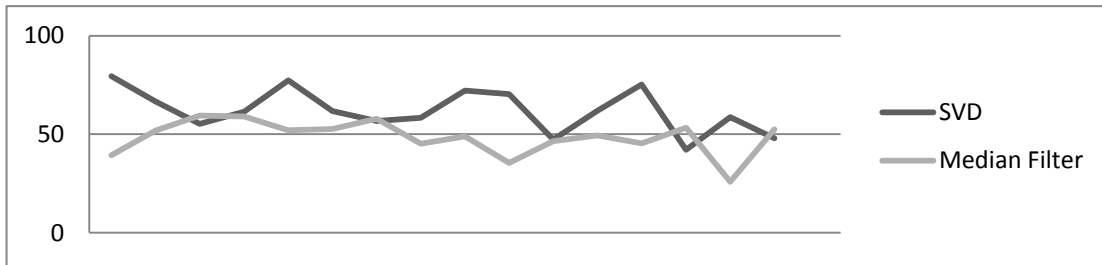
Fig. 3 Flow chart shows the work flow of SVD based Noise Detection and Removal Model.

VIII. RESULTS

The experimental results carried out for four different given image sets. Using the linear equation (refer in pseudo code) percentage of noise present in image can be estimated. After calculating noise, SVD based noise removal technique is applied to successfully generate a noise free image. Noise estimations and removing details in form of tables are also shown below. Also the graphical representation of comparative analysis between Noise removals by proposed SVD model with that by Median Filter of different images sets is represented below to show the extent of noise removal. The compared results shows that the proposed SVD based noise removal model is somehow efficient than that of the existing methods. The proposed model removes the noise from digital images up to a great extent. The corresponding graphs establish a connection between the proposed and the existing one with respect to their efficiency of noise removal from different digital image data sets. The flow of the two different curves shows the percentage of noise removal from digital images.

Image	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	I12	I13	I14	I15	I16
SVD	79.5203	66.6481	55.2520	61.5025	77.3401	61.7066	56.7786	58.4282	72.1758	70.3194	47.3395	61.9837	75.2738	42.1469	58.6232	48.0161
Median Filter	39.2848	51.9195	59.5059	59.051	52.0238	52.5959	57.7948	45.2492	48.909	35.5002	46.4758	49.3855	45.2821	53.3455	25.9006	52.4999

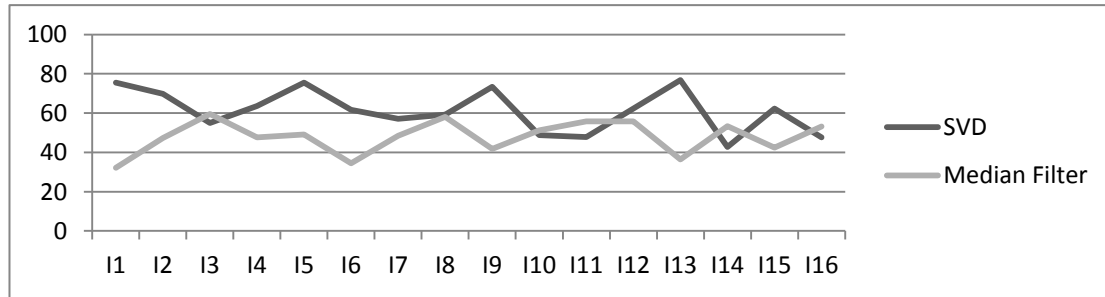
Table 1. Comparative analysis of Noise Removal by SVD and By Median Filter with Salt & Pepper Noise= 0.1



Graph 1: Graphical Representation of Noise Removal by SVD and By Median Filter with Salt & Pepper Noise= 0.1

Image	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	I12	I13	I14	I15	I16
SVD	75.4334	69.7797	54.9081	63.5231	75.5570	61.6953	56.9948	59.1793	73.3426	48.778	47.8608	62.3256	76.7747	42.7818	62.2603	47.6567
Median Filter	32.1341	47.2692	59.5059	47.6229	49.1447	34.4474	48.4091	58.1076	41.8189	51.1648	55.802	55.7084	36.406	53.3455	42.359	53.2235

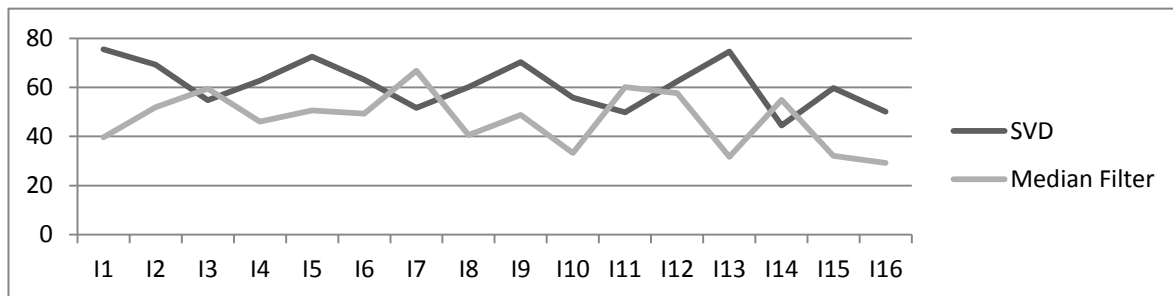
Table 2. Comparative analysis of Noise Removal by SVD and By Median Filter with Salt & Pepper Noise= 0.2



Graph 2: Graphical Representation of Noise Removal by SVD and By Median Filter with Salt & Pepper Noise= 0.2

Image	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	I12	I13	I14	I15	I16
SVD	75.4734	69.3155	54.7401	62.7916	72.5090	63.1051	51.7081	60.1656	70.3194	55.8021	49.8017	62.4871	74.5962	44.4830	59.7859	50.1208
Median Filter	39.6331	51.9195	59.5059	46.0319	50.6478	49.3723	66.7679	40.5981	48.7780	33.2725	60.1448	57.6116	31.7174	54.9466	32.0861	29.2553

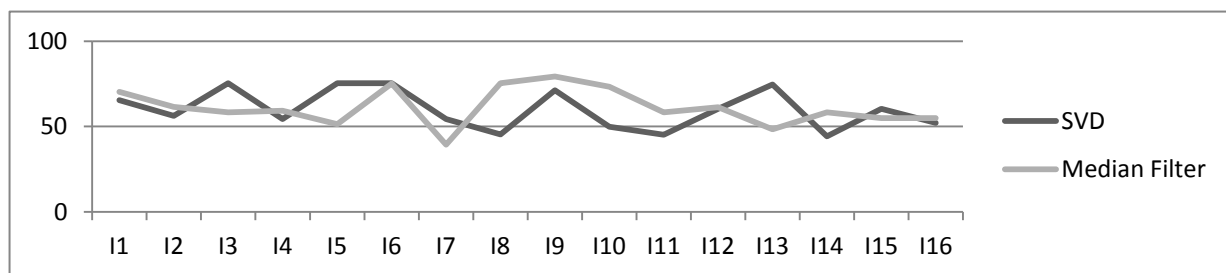
Table 3. Comparative analysis of Noise Removal by SVD and By Median Filter with Salt & Pepper Noise= 0.3



Graph 3: Graphical Representation of Noise Removal by SVD and By Median Filter with Salt & Pepper Noise= 0.3

Image	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	I12	I13	I14	I15	I16
SVD	65.4857	56.2587	75.2546	54.2564	75.2554	75.2554	54.2554	45.2588	71.2546	49.8017	45.2154	60.2546	74.5478	44.2145	60.2546	52.0871
Median Filter	70.2545	61.5285	58.2554	59.2546	51.2789	75.2001	39.2546	75.2548	79.2155	73.3426	58.2546	61.2547	48.2549	58.2545	54.9466	54.9466

Table 4. Comparative analysis of Noise Removal by SVD and By Median Filter with Salt & Pepper Noise= 0.4



Graph 4: Graphical Representation of Noise Removal by SVD and By Median Filter with Salt & Pepper Noise= 0.4

IX. CONCLUSION AND FUTURE WORK

The proposed SVD based noise detection and removal model gives satisfactory results up to great extent. In our research study, only simpler geometrical shapes are under consideration for carried out the experiment. This proposed model can further extended for complex and real time images. More efficient results shall be generated by improving the proposed SVD model compared with other filters.

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