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The novel noise classification techniques found on quadruple threshold statistical detection filter under fix intensity impulse outlier environment

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ABSTRACT

Because of the enormous necessity of contemporary noise suppressing algorithms, this article proposes the novel noise classification technique found on QTSD filter improved from the TTSD filter. The four thresholds for each auxiliary situations are incorporated into the proposed QTSD framework for dealing with the limitation of the earlier noise classification technique. The mathematical pattern is modeled by each photograph elements and is investigated in contradiction to the 1st threshold for analyzing whether it is non-noise or noise photograph elements. Subsequently, the calculated photograph element is analyzed with the contradiction between the 2nd threshold, which is modeled by using the normal distribution (mean and variance), and is analyzed with the contradiction between the 3rd threshold, which is modeled by using the quartile distribution (median). Finally, the calculated photograph element is investigated in contradiction to the 4th threshold, which is modeled from maximum or minimum value for analyzing whether it is non-noise or noise photograph elements FIIN. For performance evaluation, extensive noisy photographs are made up of nine photographs under FIIN environment distribution, which are synthesized for investigating the proposed noise classification techniques found on QTSD filter in the objective indicators (noise classification, non-noise classification and overall classification correctness). From these results, the proposed noise classification technique can outstandingly produce the higher correctness than the earlier noise classification techniques.

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1. INTRODUCTION

In the course of twenty-five years, almost contemporary advance noise suppressing algorithms [1]-[5], which are commonly incorporated of two fundamental procedures: the noise classification technique and the noise recovery technique, have been extensively investigated and developed from the extensively implemented domains [6]-[9]. As a result, the noise classification technique is highly dominant to the overall effectiveness of noise suppressing algorithms thereby extensive advance noise suppressing algorithms [10]-[22] are investigated and developed for both noise classification techniques and noise recovery techniques as following. In 1975, the noise suppressing algorithm found on a standard median filter (SMF) [20] was initially introduced for (fix intensity impulse outlier) FIIN thus the SMF is one of the practical complexity with acceptable effectiveness. For recovering FIIN on color electronic photographs in 1990, the vector median filter (VMF) [10], which is improved from SMF, is proposed and, late, the VMF will become of one the high effective noise suppressing algorithm for color electronic photographs. The noise suppressing algorithm [11] based on intensity preserving cast removal and particle swarm optimization for color images was proposed in 2017. Consequently, automatic computer-assisted diagnosis algorithm [12] based on SVM classification for MRI brain images was proposed in 2017. In 2018, the noise suppressing algorithm [13] based on noise level estimation using local statistics was proposed for digital Image. Next, the noise suppressing algorithm [14] based on an efficient filtering technique was proposed for color images in 2018. Later, the classical noise suppressing algorithm based on Wiener and Gaussian filtering [15] been analyzed its performance by varying kernel size in 2019. Subsequently, the noise suppressing algorithm based on filter technique [16] been analyzed its performance on medical images in 2019. Bilal Charmouti *et al*. [17] reviews many noise suppressing algorithms based on different fundamental techniques and comparatively simulates these performances on denoising perspective in 2019. The modified noise suppressing algorithms based on a fractional wavelet technique [18], which is the extended Haar wavelet as fractional order by a low-pass filtering generalization with the fractional delay process, has been proposed in 2020. In 2020, the noise suppressing algorithm based on discrete wavelet transform [19] using with noise density estimation was proposed for underwater acoustic noise. Next, the noise suppressing algorithm found on an adaptive median filter (AMF) [21], which was developed from the SMF for automatically adjusting the computational area, was introduced for FIIN in 1994 therefore the AMF is one of the practical complexity with high effectiveness. Many modern noise suppressing algorithms [22]-[25], which are traditionally comprised of the noise classification technique and the noise recovery technique, have been proposed as following. A hybrid statistical noise suppression technique [22] has been proposed for suppressing impulse noise in 2017. Next, another effective noise suppressing algorithm, adaptive decision based inverse distance weighted interpolation (DBIDWI) algorithm [23], [24], which was proposed for high density salt and pepper noise by V. Kishorebabu *et al*. [24] in 2017, has been analyzed its performance [23] for suppressing impulse noise for all density salt and pepper noise in 2019. The modern noise classification techniques [25] such as ROAD, ROLD and RORD are comparatively analyzed for detecting impulse noise in 2019. Later, the noise suppressing algorithm found on the triple threshold statistical detection (TTSD) filter [26] in 2018 was introduced and the noise suppressing algorithm has very impressive effectiveness for random intensity impulse noise (RIIN). As a results, the TTSD has been analyzed its performance [27] for suppressing impulse noise for all density salt and pepper noise in 2019. Improved from the outstanding TTSD filter, this article proposes the novel noise classification technique found on QTSD for FIIN [28].

2. THE PROPOSED QTSD FILTER FOR THE NOISE CLASSIFICATION TECHNIQUE

Delineate that $\boldsymbol{x}$ is the non-noise photograph, which are consolidated of an photograph element $x_{i,j}$ at point (i,j), where $0 \leq x_{i,j} \leq 255$ or $[0,255]$ is characterized as the magnitude space of this photograph. Next, $\boldsymbol{y}$ is an noise photograph that are consolidated of an noise photograph element $y_{i,j}$. As a results, $y_{i,j}$ can be conceptually declared as statement.

$$y_{i,j} = \begin{cases} 0 & \text{atprobability } p \\ 255 & \text{atprobability } q \\ x_{i,j} & \text{atprobability } (1-p-q) \end{cases} \tag{1}$$

where $(p-q)$ is the FIIN denseness

The conceptual process of the QTSD filter [28] for classifying the impulsive noise can be declared as sub-process:

a. Declare the filter size to be 5×5 (A) at center $y_{i,j}$ and, later, estimate the first statistical moment (μ_A) and the second statistical moment (σ_A) of each elements within window area A except the center element.
b. Estimate the absolute subtraction (p_{ij}) of each elements in this A window and μ_A, later, write down 24 enumerated values (p_{ij}).
c. Estimate the first statistical moment (μ_P) and the second statistical moment (σ_P) of each 24 enumerated values (p_{ij}).

$$T_1 = \mu_P + \sigma_P \tag{2}$$

d. Estimate the absolute subtraction q_{ij} of the center element $y_{i,j}$ and other 24 neighbor elements in this A window.
e. Estimate the first statistical moment (μ_q) from all absolute subtraction q_{ij} and identify the noise signature (NS) as

$$NS = \mu_q \tag{3}$$

f. The $y_{i,j}$ will be detected as outlier element where $NS \geq T_1$ and $((y(i,j) = T_{4min}())$ or $(y(i,j) = T_{4max}()))$ otherwise go to sub-process 7.
g. Estimate the second constant T_2 that is characterized by the Gaussian distribution model (the first and the *second* statistical moment) as

$$TA_{A_{2min}} \tag{4}$$

and

$$TA_{A_{2max}} \tag{5}$$

h. The $y_{i,j}$ is characterized as a outlier element where If $(y_{i,j} \leq T_{2min}$ or $y_{i,j} \geq T_{2max})$ and $((y(i,j) = T_{4min}())$ or $(y(i,j) = T_{4max}()))$ otherwise go to sub-process 9.
i. Estimate the third constant T_3 that is characterized by quartile distribution model (median) as

$$T1_{3min} \tag{6}$$

and

$$T3_{3max} \tag{7}$$

j. The $y_{i,j}$ is characterized as a outlier element where $(y_{i,j} \leq Q_1$ or $y_{i,j} \geq Q_3)$ and ($(y(i,j) = T_{4min}())$ or $(y(i,j) = T_{4max}()))$ otherwise $y_{i,j}$ is a characterized as genuine element.

In order to illustrate the noise classification process of the QTSD filter, the extensive sub-process of the proposed noise classification technique can be illustrated as Figure 1 in appendix.

3. EXPERIMENTAL SIMULATION RESULTS

The experimental simulation investiages the QTSD filter in noise classification performance (in the first section) and overall noise suppressing performance (in the second section). The MATLAB software is utilized in these simulation, which are implemented on workstations with the hardware condition: Intel i7-6700HQ CPU with 16 GB main memory where each workstation is executed on different extensive noisy photographs under FIIN distributions. In these first experimental simulation, the correctness performance of the proposed QTSD filter are analyszed on nine noise photographs (Lena, M-calendar, Pepper, Pentagon, Girl, Mandrill, House, Airplane), which are caused by FIIN with bountiful noise denseness from 5% to 90%. The classification correctness of noise elements shall be conceptually declared as following statement.

$$\mathrm{Acc}_{\mathrm{noisy}} = \sum_{\substack{\forall\,\mathrm{noisy}\\ \mathrm{pixels}}} \left(\hat{y}_{\mathrm{estimated\ noisy\ pixels}} \big/ y_{\mathrm{noisy\ pixels}} \right) \tag{8}$$

The classification correctness of non-noise elements shall be conceptually declared as following statement.

$$\mathrm{Acc}_{\mathrm{noiseless}} = \sum_{\substack{\forall\,\mathrm{noiseless}\\ \mathrm{pixels}}} \left(\hat{y}_{\mathrm{estimated\ noiseless\ pixels}} \big/ y_{\mathrm{noiseless\ pixels}} \right) \tag{9}$$

The overall classification correctness of both noise and non-noise elements shall be experimentally characterized as upcoming actuarial calculation comment.

$$\mathrm{Accc}_{\mathrm{overall}} = \left(\tfrac{1}{2} \sum_{\substack{\forall\,\mathrm{noisy}\\ \mathrm{pixels}}} \left(\frac{\hat{y}_{\mathrm{estimated\ noisy\ pixels}}}{y_{\mathrm{noisy\ pixels}}} \right) + \tfrac{1}{2} \sum_{\substack{\forall\,\mathrm{noiseless}\\ \mathrm{pixels}}} \left(\frac{\hat{y}_{\mathrm{estimated\ noiseless\ pixels}}}{y_{\mathrm{noiseless\ pixels}}} \right) \right) \quad (10)$$

These simulation results of QTSD filtering classification correctness of noise elements, non-noise elements and overall noise and non-noise elements for noise denseness, which is correlatively analyzed with the recent powerful TTSD filter (that is proposed in 2018), from 5% to 90% are illustrated in Table 1, Table 2 and Table 3, respectively.

Table 1. The simulated result of noise classification correction of the proposed QTSD filter

Tested Images	FIIN Noise Denseness (%)								
	5	10	15	20	25	30	35	40	45
Lena (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Lena (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
M-cal (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
M-cal (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Pepper (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Pepper (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Penta (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Penta (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Girl (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Girl (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Resolution (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Resolution (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Mandrill (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Mandrill (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
House (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
House (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Airplane (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Airplane (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Average (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Average (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Tested Images	FIIN Noise Denseness (%)								
	50	55	60	65	70	75	80	85	90
Lena (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Lena (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
M-cal (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
M-cal (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Pepper (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Pepper (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Penta (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Penta (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Girl (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Girl (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Resolution (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Resolution (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Mandrill (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Mandrill (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
House (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
House (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Airplane (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Airplane (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Average (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Average (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Table 2. The simulated result of non-noise classification correction of the QTSD filter

Tested Images	FIIN Noise Denseness (%)								
	5	10	15	20	25	30	35	40	45
Lena (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Lena (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
M-cal(TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
M-cal(QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Pepper (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Pepper (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Penta (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Penta (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Girl (TTSD)	0.7032	0.7054	0.7056	0.7032	0.6991	0.6934	0.6841	0.6747	0.6639
Girl (QTSD)	0.7491	0.7466	0.7433	0.7397	0.7370	0.7335	0.7295	0.7252	0.7191

Table 2. The simulated result of non-noise classification correction of the QTSD filter (*continue*)

Resolution (TTSD)	0.1946	0.1837	0.1729	0.1628	0.1527	0.1400	0.1356	0.1241	0.1111
Resolution (QTSD)	0.1957	0.1846	0.1738	0.1639	0.1535	0.1409	0.1364	0.1246	0.1118
Mandrill (TTSD)	0.9987	0.9988	0.9989	0.9991	0.9990	0.9991	0.9991	0.9992	0.9991
Mandrill (QTSD)	0.9994	0.9994	0.9995	0.9996	0.9995	0.9995	0.9995	0.9996	0.9995
House (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
House (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Airplane (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Airplane (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Average(TTSD)	0.8774	0.8764	0.8753	0.8739	0.8723	0.8703	0.8688	0.8664	0.8638
Average(QTSD)	0.8827	0.8812	0.8796	0.8781	0.8767	0.8749	0.8739	0.8722	0.8700
Tested Images	FIIN Noise Denseness (%)								
	50	55	60	65	70	75	80	85	90
Lena (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Lena (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
M-cal(TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
M-cal(QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Pepper (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Pepper (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Penta (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Penta (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Girl (TTSD)	0.6551	0.6452	0.6345	0.6246	0.6122	0.6028	0.5905	0.5747	0.5577
Girl (QTSD)	0.7132	0.7046	0.6961	0.6861	0.6747	0.6643	0.6505	0.6334	0.6137
Resolution (TTSD)	0.1018	0.0907	0.0827	0.0722	0.0649	0.0506	0.0413	0.0294	0.0209
Resolution (QTSD)	0.1025	0.0913	0.0833	0.0727	0.0650	0.0509	0.0415	0.0296	0.0209
Mandrill (TTSD)	0.9992	0.9994	0.9994	0.9994	0.9994	0.9993	0.9991	0.9987	0.9984
Mandrill (QTSD)	0.9996	0.9996	0.9996	0.9996	0.9997	0.9995	0.9993	0.9990	0.9987
House (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
House (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Airplane (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Airplane (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Average(TTSD)	0.8618	0.8595	0.8574	0.8551	0.8529	0.8503	0.8479	0.8448	0.8419
Average(QTSD)	0.8684	0.8662	0.8643	0.8620	0.8599	0.8572	0.8546	0.8513	0.8481

Table 3. The simulated result of overall noise and non-noise classification correction of the proposed QTSD filter

Tested Images	FIIN Noise Denseness (%)								
	5	10	15	20	25	30	35	40	45
Lena (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Lena (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
M-cal (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
M-cal (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Pepper (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Pepper (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Penta (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Penta (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Girl (TTSD)	0.8516	0.8527	0.8528	0.8516	0.8496	0.8467	0.8421	0.8374	0.8320
Girl (QTSD)	0.8746	0.8733	0.8717	0.8699	0.8685	0.8668	0.8648	0.8626	0.8596
Resolution (TTSD)	0.5973	0.5919	0.5865	0.5814	0.5764	0.5700	0.5678	0.5621	0.5556
Resolution (QTSD)	0.5979	0.5923	0.5869	0.5820	0.5768	0.5705	0.5682	0.5623	0.5559
Mandrill (TTSD)	0.9994	0.9994	0.9995	0.9996	0.9995	0.9996	0.9996	0.9996	0.9996
Mandrill (QTSD)	0.9997	0.9997	0.9998	0.9998	0.9998	0.9998	0.9998	0.9998	0.9998
House (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
House (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Airplane (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Airplane (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Average (TTSD)	0.9387	0.9382	0.9376	0.9370	0.9362	0.9351	0.9344	0.9332	0.9319
Average (QTSD)	0.9413	0.9406	0.9398	0.9391	0.9383	0.9374	0.9370	0.9361	0.9350
Tested Images	FIIN Noise Denseness (%)								
	5	10	15	20	25	30	35	40	45
Lena (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Lena (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
M-cal (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
M-cal (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Pepper (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Pepper (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Penta (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Penta (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Girl (TTSD)	0.8276	0.8226	0.8173	0.8123	0.8061	0.8014	0.7953	0.7874	0.7789
Girl (QTSD)	0.8566	0.8523	0.8481	0.8431	0.8374	0.8322	0.8253	0.8167	0.8069
Resolution (TTSD)	0.5509	0.5454	0.5414	0.5361	0.5325	0.5253	0.5207	0.5147	0.5105

Table 3. The simulated result of overall noise and non-noise classification correction of the proposed QTSD filter (*continue)*

Tested Images	FIIN Noise Denseness (%)								
	5	10	15	20	25	30	35	40	45
Resolution (QTSD)	0.5513	0.5457	0.5417	0.5364	0.5325	0.5255	0.5208	0.5148	0.5105
Mandrill (TTSD)	0.9996	0.9997	0.9997	0.9997	0.9997	0.9997	0.9996	0.9994	0.9992
Mandrill (QTSD)	0.9998	0.9998	0.9998	0.9998	0.9999	0.9998	0.9997	0.9995	0.9994
House (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
House (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Airplane (TTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Airplane (QTSD)	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Average (TTSD)	0.9309	0.9297	0.9287	0.9276	0.9265	0.9252	0.9239	0.9224	0.9209
Average (QTSD)	0.9342	0.9331	0.9322	0.9310	0.9300	0.9286	0.9273	0.9257	0.9241

Table 4. The simulated result of proposed noise suppressing algorithms (PSNR in dB)

Tested Images	FIIN Noise Denseness (%)								
	5	10	15	20	25	30	35	40	45
Lena (TTSD)	44.1437	40.5683	38.4735	37.0012	35.4691	34.6549	33.6396	32.7912	32.1537
Lena (QTSD)	44.1437	40.5683	38.4735	37.0012	35.4691	34.6549	33.6396	32.7912	32.1537
M-cal (TTSD)	33.8265	30.7515	28.7241	27.3321	26.0929	25.1559	24.3449	23.4485	22.6226
M-cal (QTSD)	33.8265	30.7515	28.7241	27.3321	26.0929	25.1559	24.3449	23.4485	22.6226
Pepper (TTSD)	44.6517	40.9933	39.0767	37.2222	35.6168	34.6218	33.3610	32.7192	31.5482
Pepper (QTSD)	44.6517	40.9933	39.0767	37.2222	35.6168	34.6218	33.3610	32.7192	31.5482
Penta (TTSD)	41.5360	38.4091	36.4657	34.8211	33.6704	32.8752	31.9126	31.0808	30.3577
Penta (QTSD)	41.5360	38.4091	36.4657	34.8211	33.6704	32.8752	31.9126	31.0808	30.3577
Girl (TTSD)	40.9275	39.0460	37.1363	36.0495	35.1385	34.4868	33.2885	33.1268	32.4662
Girl (QTSD)	42.2002	39.9614	37.9219	37.0343	35.4994	35.1516	33.9162	33.5191	32.9332
Resolution (TTSD)	10.8895	10.7693	10.7106	10.6314	10.5477	10.3913	10.4712	10.0244	10.1557
Resolution (QTSD)	10.9906	10.8685	10.7845	10.7406	10.6264	10.4790	10.5206	10.0927	10.2053
Mandrill (TTSD)	35.6049	32.8156	31.1219	29.8013	28.6195	27.6662	26.9878	26.2291	25.5535
Mandrill (QTSD)	35.6079	32.8174	31.1234	29.8029	28.6203	27.6656	26.9890	26.2294	25.5545
House (TTSD)	43.4424	39.2905	36.8436	35.4475	33.8891	33.1098	31.8028	31.4430	30.6868
House (QTSD)	43.4424	39.2905	36.8436	35.4475	33.8891	33.1098	31.8028	31.4430	30.6868
Airplane (TTSD)	44.4395	40.0741	38.0206	36.4108	35.1259	33.9876	33.1300	32.1944	31.6389
Airplane (QTSD)	44.4395	40.0741	38.0206	36.4108	35.1259	33.9876	33.1300	32.1944	31.6389
Tested Images	FIIN Noise Denseness (%)								
	50	55	60	65	70	75	80	85	90
Lena (TTSD)	31.4062	30.7008	29.9415	29.3282	28.6491	27.7192	27.0346	26.4298	24.9663
Lena (QTSD)	31.4062	30.7008	29.9415	29.3282	28.6491	27.7192	27.0346	26.4298	24.9663
M-cal (TTSD)	22.0194	21.4728	20.8748	20.3634	19.6682	19.0352	18.4647	17.8237	16.9359
M-cal (QTSD)	22.0194	21.4728	20.8748	20.3634	19.6682	19.0352	18.4647	17.8237	16.9359
Pepper (TTSD)	31.2424	30.3661	29.5347	28.9315	28.2225	27.3633	26.4359	25.3887	24.1841
Pepper (QTSD)	31.2424	30.3661	29.5347	28.9315	28.2225	27.3633	26.4359	25.3887	24.1841
Penta (TTSD)	29.7195	29.0494	28.4674	27.7912	27.1497	26.5101	25.7817	25.0132	23.9414
Penta (QTSD)	29.7195	29.0494	28.4674	27.7912	27.1497	26.5101	25.7817	25.0132	23.9414
Girl (TTSD)	31.1927	30.7870	30.4537	29.5127	29.1430	28.0601	27.3623	26.1170	24.5832
Girl (QTSD)	31.8293	31.3880	31.0127	30.2264	29.5584	29.0116	28.3650	27.1897	26.0562
Resolution (TTSD)	9.9008	9.8114	9.4654	9.6342	9.6163	9.3103	9.3463	8.9960	8.3406
Resolution (QTSD)	9.9958	9.8880	9.6064	9.6928	9.6248	9.3385	9.3981	9.0743	8.3406
Mandrill (TTSD)	24.9107	24.3501	23.8627	23.3415	22.8220	22.2262	21.7492	21.0479	20.2954
Mandrill (QTSD)	24.9109	24.3500	23.8625	23.3416	22.8219	22.2264	21.7491	21.0466	20.2954
House (TTSD)	29.7906	29.4475	28.6620	27.2870	27.0843	25.9919	25.5637	23.8973	23.3652
House (QTSD)	29.7906	29.4475	28.6620	27.2870	27.0843	25.9919	25.5637	23.8973	23.3652
Airplane (TTSD)	30.9843	30.0582	29.1667	28.8364	28.2869	27.4683	26.7261	25.7139	24.2702
Airplane (QTSD)	30.9843	30.0582	29.1667	28.8364	28.2869	27.4683	26.7261	25.7139	24.2702

From these simulation results, classification correctness of the proposed QTSD filter has equally efficacy with the classical TTSD for six noise photographs (Lena, M-calendar, Pepper, Pentagon, House, Airplane), which is the non-full dynamic range elements ($0 < x_{i,j} < 255$) however classification correctness of the proposed QTSD has ultimately efficacy with the classical TTSD for other three noise photographs (Girl, Resolution, Mandrill), which is the full dynamic range elements ($0 < x_{i,j} < 255$). Next, the 2nd experimental simulation of efficacy (in PSNR) of noise suppressing algorithm found on QTSD filter [28], which is correlatively analyzed with the classical TTSD filter [28], are illustrated in Table 4 under noise denseness from 5% to 90%. From these simulation results, the efficacy of noise suppressing algorithm found on QTSD filter and modified AMF [26]-[28] has equally efficacy with the classical TTSD for six noise photographs (lena, m-calendar, pepper, pentagon, house, airplane). However, classification correctness of the proposed QTSD has ultimately efficacy with the classical TTSD for other three noise photographs. (Girl, Resolution, Mandrill). Because of page obstruction, a few part of simulation results of Girl that are suppressed by QTSD, TTSD and other classical suppressing methods can be illustrated as Figure 2.

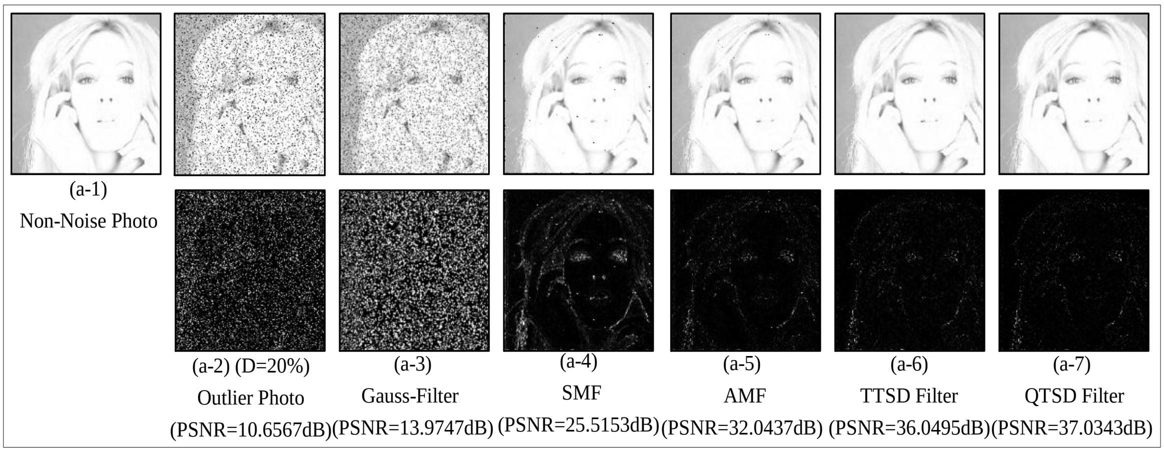

Figure 2. The few visualization simulation results of proposed noise suppressing algorithm and earlier noise suppressing algorithms

4. CONCLUSION

For suppressing FIIN, this article aims to propose the novel noise classification technique found on QTSD filter, which is ultimately improved from the outstanding TTSD filter. From these simulation results of noise classification point of view, the proposed noise classification techniques found on QTSD can definitely produce the better efficacy than the earlier noise classification techniques. Furthermore, from these simulation results of noise suppressing point of view, the proposed noise suppressing algorithm found on QTSD and modified AMF can definitely produce the better efficacy than the earlier noise suppressing algorithm. For afterward research, we will investigate and invent the better efficacy noise suppressing algorithm found on QTSD and better efficacy noise recovering technique.

APPENDIX

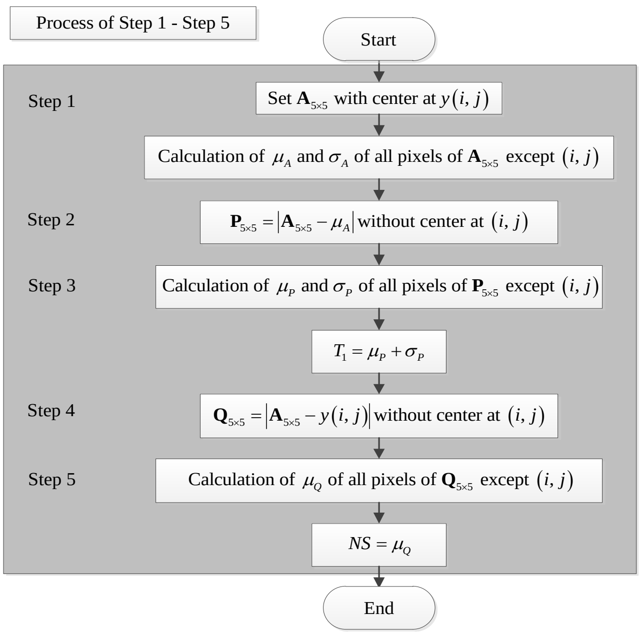

Figure 1. The extensive sub-process computation of the proposed QTSD filter

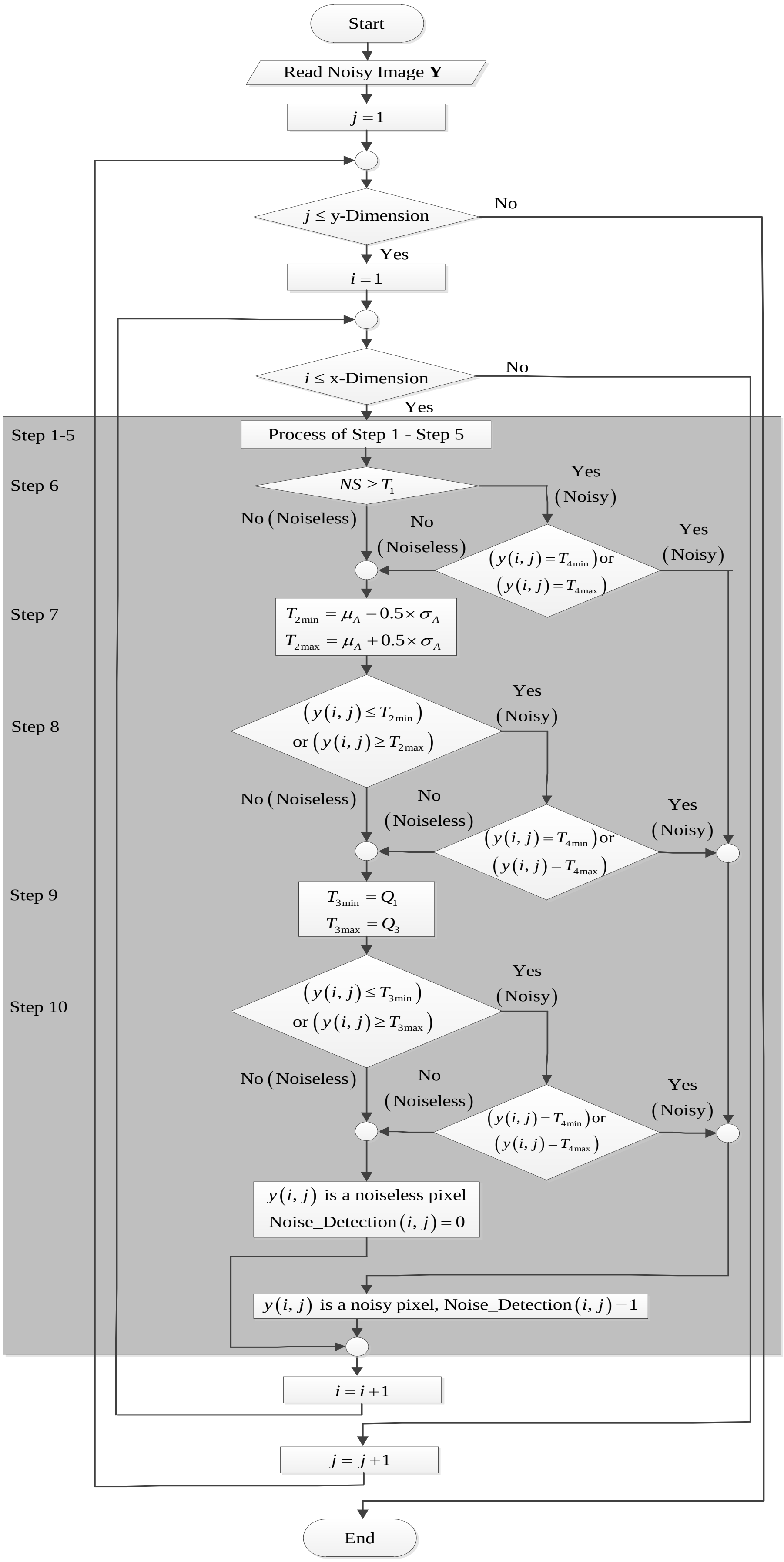

Figure 1. The extensive sub-process computation of the proposed QTSD filter (*continue*)

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