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Towards a Comprehensive Evaluation of Ultrasound Speckle Reduction

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ABSTRACT

In this paper, a new intensity and feature preservation evaluation metric for full speckle reduction evaluation is proposed based on contrast and feature similarities.

Noise-free images and simulated B-mode ultrasound images are used. This way, the despeckling techniques can be compared using numeric metrics.

CONCLUSIONS

A new evaluation metric, Speckle Reduction Evaluation Metric, is proposed based on contrast similarity map and edge preservation.

The underlying principle of SREM is that humans distinguish an image mainly based on its salient low-level features.

A total of seventeen different speckle reduction algorithms have been documented based on adaptive filtering, diffusion filtering and wavelet filtering, with sixteen qualitative metrics estimation.

SREM correlates well with other evaluation metrics.

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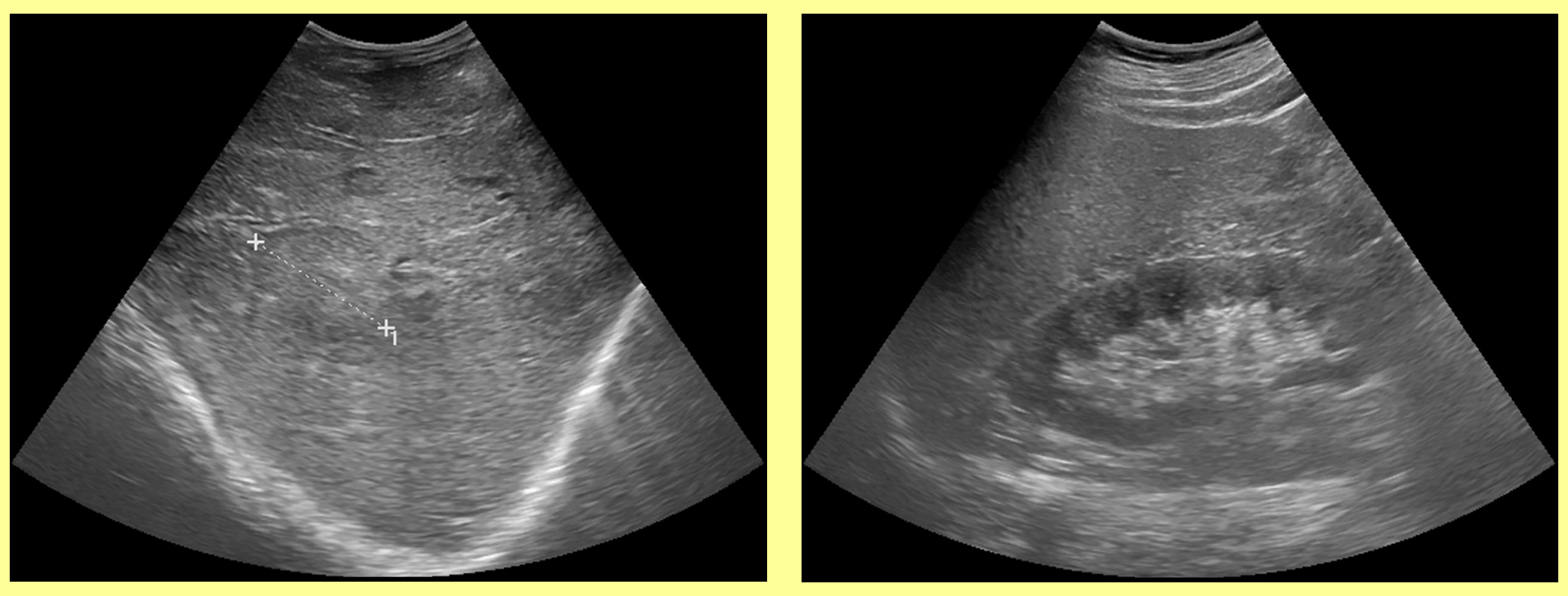
Introduction

B-mode ultrasound images are usually corrupted by the speckle artifact, which introduces fictitious structures that can not be removed by the imaging system.

The speckle reduction and the preservation of edges are in general divergent. A trade-off between noise reduction and the preservation of the image features has to be made in order to enhance the relevant image content for diagnostic purposes.

We propose a new speckle reduction evaluation metric, the SREM, that is based on the contrast and gradient similarity maps between two images.



Speckle Reduction Evaluation Metric – SREM

The computation of SREM index consists of two stages. In the first stage, the contrast similarity map (CSM) is computed, and then, we combine it with the gradient similarity map (GSM) to encode feature information.

Consider the noise free image and the filtered image. We combine mean intensity and standard deviation of each image with the covariance between them to obtain CSM. c_1 and c_2 are used to avoid instability.

$$CSM(f,g)=\frac{4\mu_f\mu_g\cdot\sigma_{f,g}}{\left(\mu_f^2+\mu_g^2+c_1\right)\cdot\left(\sigma_f^2+\sigma_g^2+c_2\right)}$$

Image is convolved with Gaussian oriented filter pairs ($F_e(\rho)$, $F_o(\rho)$) to extract the magnitude of orientation energy (OE) of edges response. The filters are parameterized by ρ that refer to *orientation*, *scale* and *elongation*.

$$OE(\rho)=\left(f*F_e(\rho)\right)^2+\left(f*F_o(\rho)\right)^2$$

$$GSM(f,g)=\frac{2\cdot OE_f\cdot OE_g+t}{OE_f+OE_g+t}$$

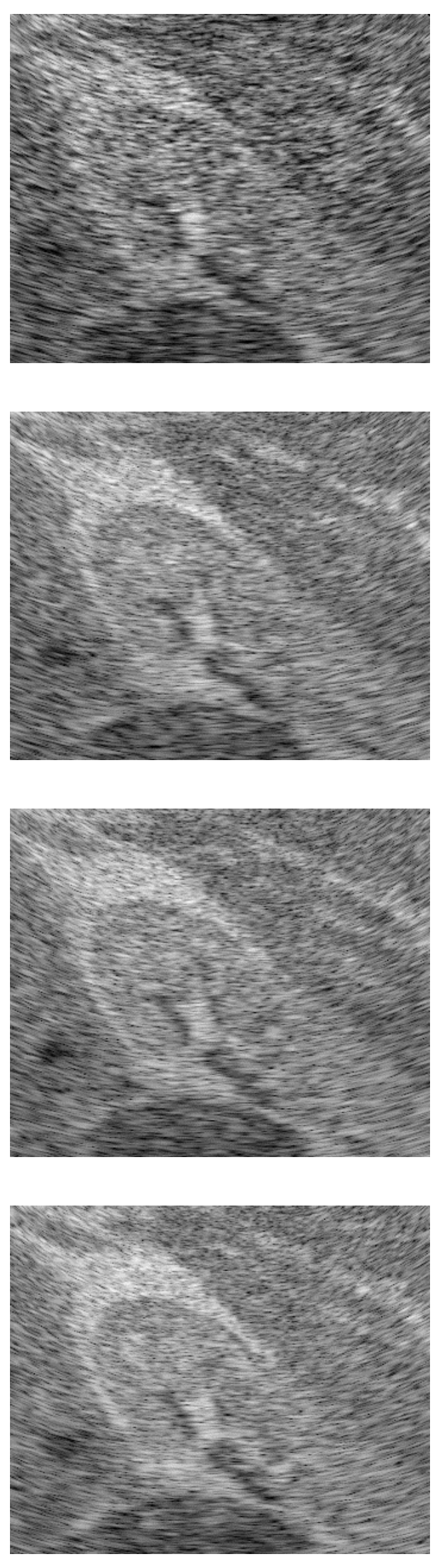
At each pixel I, we can define the dominant orientation energy ($OE_i(\rho)^*$) and the parameter (ρ_i^*) as the maximum energy across scale, orientation and elongation.

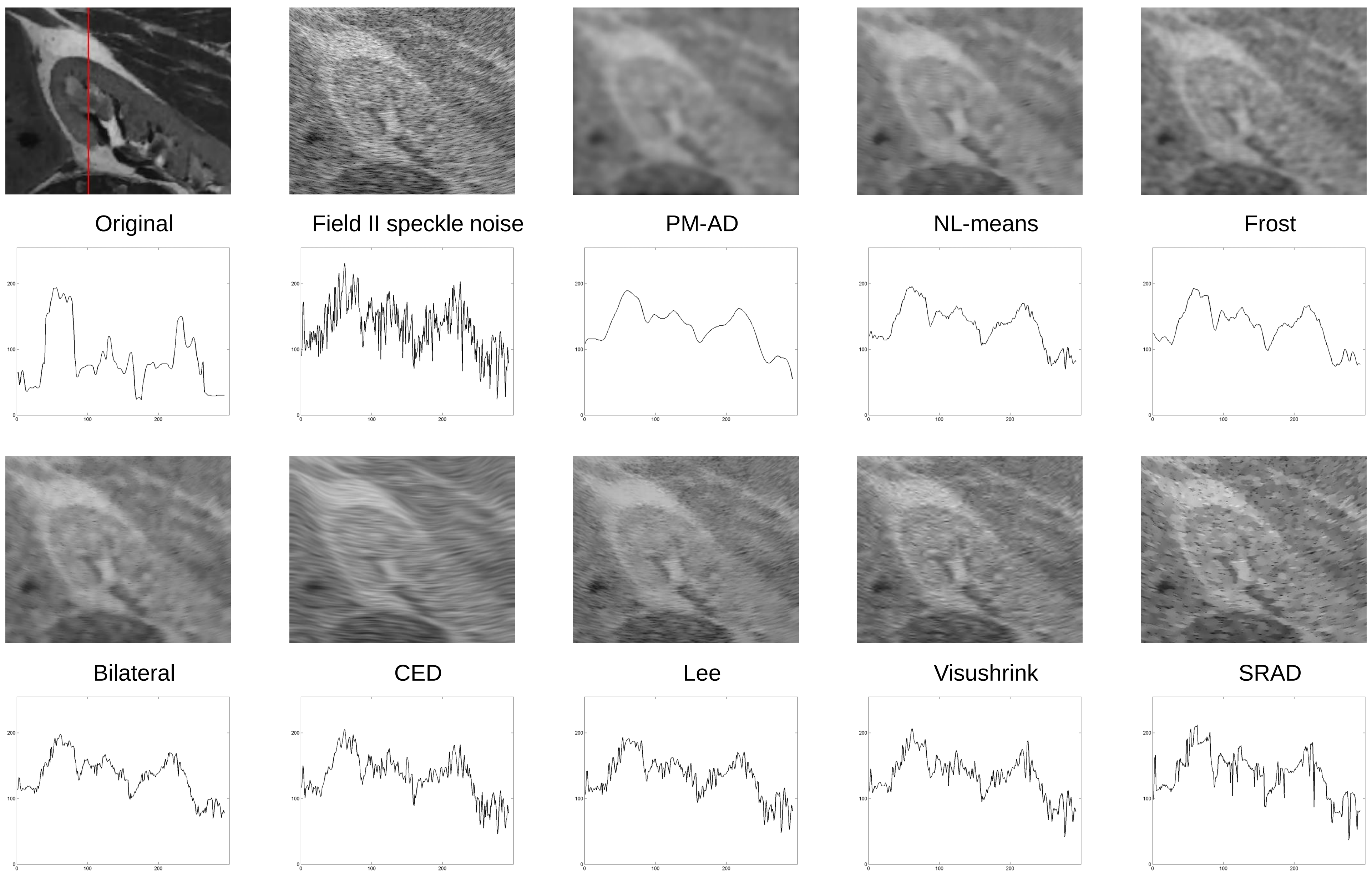
$$OE_i(\rho)^*=\max OE(\rho) \qquad \rho_i^*=\arg\max OE(\rho)$$

$$SREM=\frac{\sum CSM(i,j)\cdot GSM(i,j)}{\sum GSM(i,j)}$$

Experimental Results

Field II simulation





Filters	RMSE ↓	MD ↓	AD ↓	NAE ↓	SC ↓	SNR ↑	PSNR ↑	LMSE ↑	UQI ↑	NK ↑	CoC ↑	MSSIM ↑	M3SIM ↑	QILV ↑	GSM ↑	SREM ↑
PM-AD	69.19	141.78	62.22	0.96	0.34	6.84	11.37	1.06	0.06	1.56	0.59	0.49	0.23	0.01	0.97	0.72
NL-means	72.61	152.00	65.88	1.01	0.32	6.59	10.94	1.25	0.06	1.60	0.58	0.46	0.23	0.02	0.97	0.69
Frost	70.03	148.33	62.85	0.97	0.34	6.77	11.26	1.10	0.06	1.57	0.57	0.45	0.22	0.02	0.97	0.69
Median	71.08	151.22	63.86	0.99	0.33	6.70	11.13	1.86	0.06	1.58	0.56	0.45	0.22	0.03	0.97	0.67
EEAD	69.08	162.00	61.19	0.95	0.34	6.83	11.38	20.46	0.06	1.55	0.54	0.46	0.23	0.04	0.97	0.67
Bayes	70.30	158.11	62.90	0.97	0.34	6.75	11.23	1.07	0.05	1.57	0.56	0.44	0.22	0.04	0.97	0.66
Sure	70.30	158.11	62.90	0.97	0.34	6.75	11.23	1.07	0.05	1.57	0.56	0.44	0.22	0.04	0.97	0.66
Wiener	70.05	163.78	62.54	0.97	0.34	6.76	11.26	5.54	0.05	1.57	0.55	0.42	0.21	0.06	0.97	0.62
Bilateral	70.69	151.67	63.55	0.98	0.33	6.72	11.18	3.47	0.05	1.58	0.57	0.41	0.22	0.05	0.97	0.62
Fourier	70.58	174.22	62.69	0.97	0.34	6.71	11.19	1.15	0.05	1.57	0.53	0.41	0.20	0.05	0.97	0.60
LMMSE	70.68	162.11	62.91	0.97	0.34	6.71	11.18	1.16	0.05	1.57	0.54	0.38	0.20	0.07	0.97	0.57
Butter	70.86	179.22	62.09	0.96	0.32	6.78	11.15	1.83	0.05	1.62	0.59	0.37	0.24	0.12	0.97	0.54
CED	70.55	155.78	62.92	0.97	0.34	6.72	11.20	3.28	0.04	1.57	0.54	0.32	0.19	0.06	0.96	0.44
Lee	70.35	156.44	62.75	0.97	0.34	6.73	11.22	5.44	0.04	1.57	0.54	0.33	0.20	0.09	0.96	0.44
Visu	70.74	167.00	62.93	0.98	0.34	6.70	11.17	4.30	0.04	1.57	0.53	0.30	0.19	0.08	0.96	0.41
Kuan	70.47	157.56	62.78	0.97	0.34	6.72	11.21	6.11	0.04	1.57	0.54	0.31	0.19	0.09	0.96	0.41
SRAD	74.30	176.11	66.31	1.03	0.32	6.45	10.74	15.79	0.04	1.61	0.51	0.29	0.18	0.08	0.95	0.37
Noisy	73.60	189.33	62.91	0.99	0.33	6.44	10.82	59.55	0.02	1.57	0.42	0.11	0.14	0.02	0.92	0.12
PCC	1.91	7.44	1.93	1.76	2.09	1.62	1.49	186.46	23.24	1.11	6.91	23.94	11.21	56.60	1.18	28.41

From the analysis of PCC we can see that most of the metrics have a low variation in their evaluations. The exception are the LMSE, MMSIM, UQI, QILV and SREM. However, as LMSE quantifies only the average distortion in edge pixel locations between each filtered image it does not evaluate the speckle reduction inside the regions. Metrics UQI and QILV give very low values which difficult the noise reduction evaluation. MMSIM uses only the contrast intensity information.

The comprehensive form of SREM enables a reliable metric for speckle noise reduction evaluation that takes into account the similarity in intensity and the preservation of edges.