Nonlocal Means-Based Speckle Filtering for Ultrasound Images

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There have been many works on localized image de-noising like simple averaging, Gaussian filtering, Median Filtering and also works on non local image de-noising like the work by *Buades et al.*[1], also then came up the using of Blockwise Non local image de-denoising by *Coupe et al.*[2] and in the specific case of UltraSound images where the noise is mostly speckle noise the above 2 methods did work quite well but the work by *Coupe et al.*[3] combining their previous work on Blockwise image filtering and introducing a new patch comparison *Pearson Distance* proved to be better than the previous works.

In this work I reproduce the results by the latter work and compare it with the existing local as well as the non local filtering techniques.

1 Blockwise Non Local Image Filtering

The blockwise approach consists of: *i) dividing the volume into blocks with over- lapping supports; ii) performing a NL-means-like restoration of these blocks; iii) restoring the pixel intensities from the restored blocks.* So essentially we take overlapping boxes b_{ik} of size 3×3, around every pixel i (In my implementation I have considered $k = 4$). Now for every pixel i, we also consider a search window Ω of size 10×10 and we use *Pearson Distance* similarity to compare box at i and j ($j \in \Omega$). This similarity is the weight given to the pixel value in the image at j.

$$NL(u)(B_{i_k}) = \sum_{B_j \in \Omega} w(B_{i_k}, B_j) u(B_j) \tag{1}$$

where $NL(u)$ is the restored image and $w(B_{i_k}, B_j)$ is given by:

$$\frac{1}{Z_{i_k}} e^{-\left(\frac{d_P\left(u(B_{i_k}), u(B_j)\right)}{h^2}\right)} \tag{2}$$

where d_P is the *Pearson Distance*

2 Pearson Distance

Pearson Distance is a similarity measure between 2 boxes B_{i_k} and B_j defined as:

$$d_P\left(u(B_{i_k}), u(B_j)\right) = \sum_{p=1}^{P} \frac{\left(u^{(p)}(B_i) - u^{(p)}(B_j)\right)^2}{\left(u^{(p)}\right)^{2\gamma}(B_j)} \tag{3}$$

where $\gamma = 0.5$ in all the experiments.

3 Experiments

Experiments are performed on Artificially generated *phantoms* and also on the real time data of US images. For the phantoms, speckle noise is added and then various filtering techniques are applied to remove the speckle noise where as for the real time data, no additional noise is added.

The results are compared against the following methods:

1. Lee Filter
2. Kuan Filter
3. Frost Filter
4. NL Means Denoising Filter (NL)
5. Blockwise NL means Denoising Filter with Pearson Distance Similarity (BNLPD)

3.1 Synthetic Experiments

These experiments are done on artificially generated phantom. In *Figure 1*, the variance (σ) of the added speckle noise is 0.4.

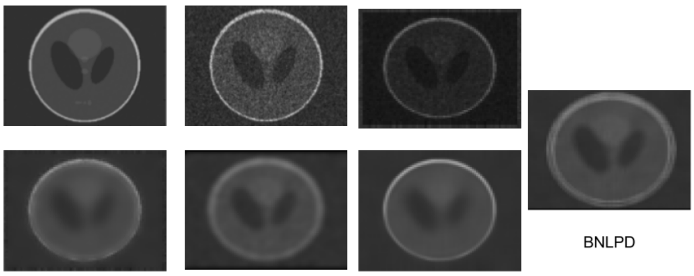

Figure 1: Various local and non local image filterings on artificial phantom corresponding to $\sigma = 0.4$. *BNLPD* is the output of the propose model.

3.2 Real Data Experiments

Experiments were also done on Real Data. The US dataset was taken from `http://splab.cz/en/download/databaze/ultrasound`. It composed of US images of the common carotid artery of 10 volunteers. *Figure 2* shows the comparison between different filterings on the real data.

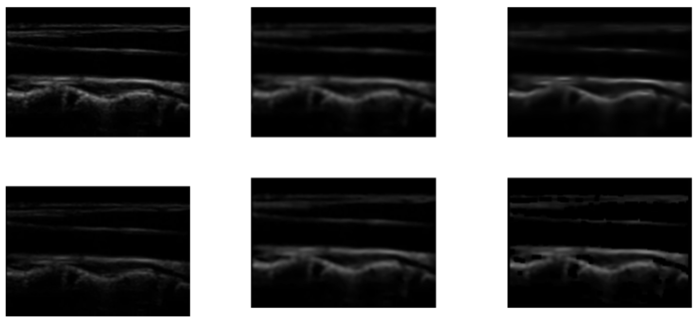

Figure 2: Various local and non local image filterings on Real US data *BNLPD* is the output of the propose model.

SNR	
Filter	$\sigma = 0.4$
Phantom	17.9426
Lee	17.0206
Kuan	14.8839
Frost	13.7415
NL	14.2836
BNLPD	10.6996

Table comparing the SNR values of different Filters used for the added noise with $\sigma = 0.4$. We can clearly see that BNLPD (proposed method with Pearson Distance Similarity) outperforms others in SNR value by having the minimum value.

4 References

[1] Jean-Michel Morel Antoni Buades, Bartomeu Coll. A non-local algorithm for image denoising.

[2] Prima S Hellier P Kervrann C Barillot C. Coupe P, Yger P. An optimized blockwise nonlocal means denoising filter for 3-d magnetic resonance images, 2008. IEEE Trans Med Imaging.

[3] Charles Kervrann Pierrick CoupÃľ, Pierre Hellier and Christian Barillot. Nonlocal means-based speckle filtering for ultrasound images, 2009. IEEE TRANSACTIONS ON IMAGE PROCESSING.