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Non Local Means Denoising in Photoacoustic Imaging

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1. Introduction

Photoacoustic microscopy is the biomedical imaging modality to visualize the obeject which absorbs the light. Photoacoustic imaging has received outstanding attention, due its safety, penetration depth and high contrast. The sample or object and transducer should be mediated by water or ultrasound gel, because the ultrasound wave propagates very slow in the air.

The photoacoustic imaging process is given as follows: (i) pulsed laser irradiated the sample, (ii) the temperature of sample will be increased, (iii) this thermal expansion creates the acoustic waves, (iv) we detect the the acoustic wave by using the ultrasound transducer, then (v) the computer is used to reconstruct the image. In Fig. 1, we show the schematic diagram of photoacoustic imaging system.

The quality of photoacoustic images normally contaminated with noise due to some parameters such as time delay of photoacoustic wave, frequency, tranducer dimension and random noise from laser.

The non local means denoising (NLMD) is the denoising method to replacing all of the pixel in image by computing weighted average of nearby similar patches[1]. The NLMD is already successfully applied to the magnetic resonance image[2].

In this work, we will show the application of NLMD to eliminate noise and enhance the image quality of photoacoustic image.

2. Method

In this work, we applied the band pass filter then NLMD method. NLMD assuming that the image contains of redundancy or similarity. The photoacoustic image usually contains of the blood vessel or soft tissue, so the photoacoustic image, normally contains of redundancy and similarity. Please see Fig. 2. for the real example of photoacoustic image.

The basics idea of NLMD is very simple. In the image, there are several similar patches. Each patch contain of signal and noise. If we take weighting average of these patches, we will reduce the noise, because the noise is assumed to be random value. The NLMD take the average value of the several patches with consider the weighting factor w.

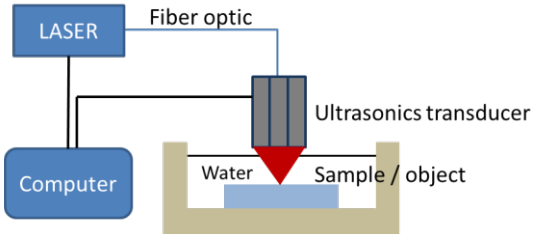

Fig. 1 Schematic diagram of photoacoustic imaging system.

The algorithm used in this work is based on the algorithm written by Antoni Buades, *et al* [1]. The denoising of grayscale image u for given pixel p is written as[1],

$$\hat{u}(p) = \frac{1}{C(p)} \sum_{q \in B(p,r)} u(q) w(p,q), \qquad (1)$$

where p is the original pixel position, $C(p)$ is normalization factor, q is the neighborhood pixel position, and w weighting factor for averaging. $C(p)$ its self is define as[1],

$$C(p) = \sum_{q \in B(p,r)} w(p,q) \qquad (2)$$

The weighting factor $w(p,q)$ is calculated by using exponential kernel, can be formulated as[1],

$$w(p,q) = \exp\left(\frac{-\max(d^2 - 2\sigma^2, 0.0)}{h^2} \right), \qquad (3)$$

where σ denote the standard deviation of noise, h is input parameter, which described the decay of the exponential, d is the Euclidean distance which is the difference between the original patch with the neighborhood patch, d value represent the similarity between the original patch and the neighborhood patch. According to the Eq. (3) if the patch is very similar, the d value will be very small and the weighting factor will approximate to one.

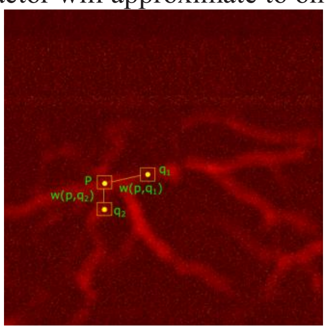

Fig. 2 The similarity patches in photoacoustic imaging image. Patches p,q_1 and q_2 are similar.

3. Result and discussion

The image that we used is produced by scanning the two micro pipes filled by carbon nanotube (CNT). We choose CNT, because it has strong absorptions in the visible and infrared regions.

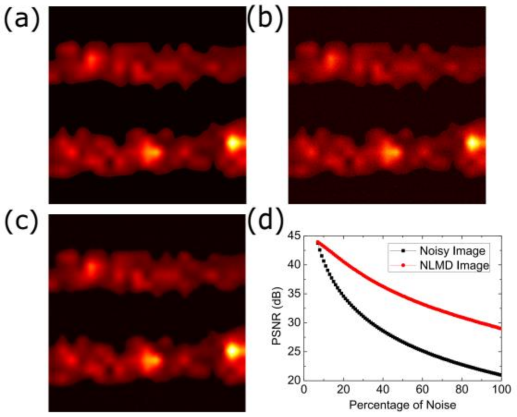

Fig. 3. (a) The extracted image from raw image, assumed does not contains noise, (b) image which contains of 60 % of random noise, (c) the denoise image by using NLMD, and (d) the PSNR as a function of percentage of noise.

We add random noise to the image Fig. 3(a), then we produce the noisy image Fig 3(b), finally we denoise the image Fig. 3(c). In Fig 3(d), we show the peak to signal ratio (PSNR) as function of the percentage of noise. We can see that, by applying the NLMD, the PSNR significantly enhance. The applied parameter in Fig. 3 are patch size 7 x 7, patch distance 9, and the *h*=0.08.

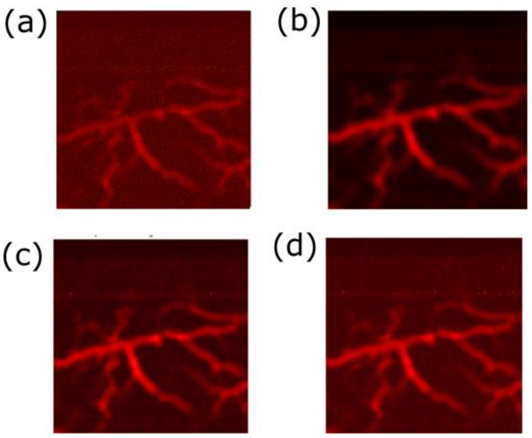

Fig. 4 (a) Raw image, (b) NLMD image with parameter; patch size 3 x 3, patch distance 17, and *h*=0.13, (c) NLMD image with parameter; patch size 7 x 7, patch distance 9, and *h*=0.08, (d) NLMD image with parameter; patch size 13 x 13, patch distance 9, and *h*=0.06

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We applied the NLMD to the real image of photoacoustic imaging. The raw image is the image of the brain vessel of mice as can be seen in Fig 4., raw data adapted from I.U. Haq *et al*[3].

Qualitatively, we can see that the image quality enhanced and the noise is reduced by applying NLMD, Fig. 4(b-d).

All of the calculation is performed by using Python 3.0 and Scikit-Image an python image processing library [4].

4. Summary

We have applied NLMD algorithm to the photoacoustic image. By applying the NLMD to the noisy photoacoustic image, the PSNR is significantly enhanced. Qualitatively, we show the image quality also enhanced.

References

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