Adaptive Noise Reduction in Ultrasound Imaging

Tuan Le

Rutgers University
New Brunswick, New Jersey
tuanle06@scarletmail.rutgers.edu

I. Objectives

The solution in assisting practitioners in venipuncture is to design a full autonomous venous access device, which integrating multiple methods of venous detection in performing precision cannula placement [1]. Particularly, B-mode ultrasound and near-infrared imaging techniques are studied to conduct vessel reconstruction. However, low light level intensity and inherent speckle noise are problematic for accurate vessel detection. Thus, an adaptive filtering method is necessary in vessel reconstruction.

II. Methods

The noise profiles of ultrasound and near-infrared images are similar to the characteristic of Gaussian noise, and only affecting at random regions. While Gaussian filter and other methods [2] can be used to smooth out the speckle noise, these methods also reduce the integrity of the image in the unaffected regions. Noise adaptive (NA) filter can be used to reduce speckle noise while preserving desirable features.

In pre-filtering operation, local statistics of [3x3] windows are calculated and used in decision making for further filtering. The measurement of median of absolute deviation (MAD) is used as the threshold in decision making of the noise mask for low light level regions [3]. Noise corrupted pixel is processed by median filter. Pixel with correlated noise in the homogeneous region has small variance ($\sigma \approx 0$), it can be calculated as the result of mean filter; in the edge transitional region, variance of local statistic is large, the de-noised pixel is approximated the original pixel value. Thus, the transitional edge area is preserved. High intensity region is filtering by the combination of median, mean, and all pass filter by the decision making from local statistics.

III. Results

Ultrasound images are acquired as the principle images in performance measurement. Fifteen sample images are added noise and filtered using NA filter, Gaussian filter, and median filter; normalized mean squared errors are calculated and compared for quantification of performances. Several thousand trials of multiple random noises are carried out to obtain the average performances as in Table 1. In Figure 1, NA filter (top) has much better performance comparing to Gaussian filter (centre) in speckle noise reduction; comparing between the NA filter to median filter (bottom), the top image has sharper edge at the transitional regions.

Noise adaptive filter has superior performance in speckle noise reduction of low light images. Due to similarity of noise profiles, it can be utilized in reduction of Gaussian noise [3]. From Table 1, NA filter also performs well in other type of nose such as shot noise and Poisson noise. Therefore, the filter can be used in near-infrared images; thus, reducing design complexity.

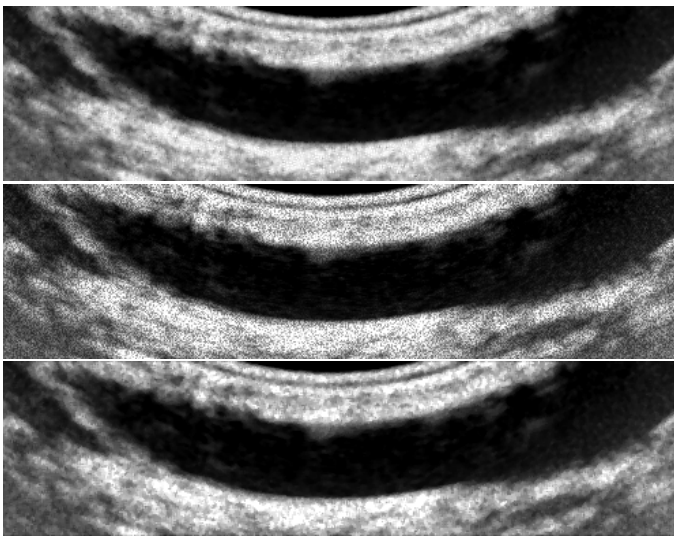

Fig. 1. NA filtered image (top); Gaussian filtered image (centre); median filtered image (bottom)

TABLE I. Normalized Mean Squared Error

filter type	NMSE			
	speckel	Gaussian	Poisson	shot noise
NA	0.0023	0.0068	0.0005	0.0011
Gaussian	0.0044	0.0165	0.0007	0.0075
median	0.0033	0.0080	0.0006	0.0004
mean	0.0023	0.0069	0.0011	0.0012

References

[1] Chen, A. et al, *Portable robot for autonomous venipuncture using 3D near infrared image guidance*, Technology, vol. 1, no. 1, pp. 1-17, Sep. 2013

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[3] Lee, S.-W., Malik, V., Jang, J.-H., Shin, J., and Paik, J., *Noise-adaptive spatio-temporal filter for real-time noise removal in low light level images*, IEEE Trans. Consumer Electronics, vol. 51, no. 2, pp. 648-653, May 2005