2P5-3

Proceedings of Symposium on Ultrasonic Electronics, Vol. 34 (2013) pp. 305-306
20-22 November, 2013

# Biomedical applications of photoacoustic imaging with LMS adaptive filter

Tai Chieh Wu[1†], Che Hua Yang[2]
([1,2] National Taipei Univ. of Technology)

**Abstract**

Photoacoustic tomography (PAT) is a novel biomedical imaging based on photoacoustic effect. It combines the advantages of both pure optical and ultrasound imaging, which can provide high ultrasonic resolution and optical contrast of soft tissue. PAT has been widely used as a diagnostic imaging tool in pre-clinical or clinical applications. In this study, we take chicken testicular for in vitro experiment. The system includes Nd:YAG pulsed laser which modulated to 710 nm and 10MHz ultrasound transducer. Generally, the image spatial resolution depends on central frequency and bandwidth of transducer. After circular scanning, the vessels image of testicular can be reconstructed in short time. For better resolution, we also use the LMS adaptive filter to obtain finer image. By using this method, the spatial resolution of the system reaches 200 μm which is better than original image twice.

## 1. Introduction

Photoacoustic (PA) imaging is based on the principles of photoacoustic effect that was first reported by Alexander Graham Bell in 1880. The basic idea of Photoacoustic tomography (PAT) is that a tissue is irradiated with nanosecond laser pulses, the conserved energy would cause a pressure rise via thermo-elastic expansion that generates photoacoustic waves. The PA waves are detected by ultrasound transducer with mechanical scanning. The image contrast of PAT is built on selective optical absorption which associated with cellular and molecular-specific of cancer. Due to this characteristic, PAT combines the contrast advantages of the optical properties and the resolution advantage of ultrasound. It's a suitable diagnostic modality for clinical applications.

Testicular cancer is the most common cancer in males between the ages of 20 to 39. The rate of this disease has more than doubled among white men in the past 40 years. In the United States, between 7,500 and 8,000 diagnoses of testicular cancer are made each year. For our study, we take chicken testicular for in vitro research. The vessels on the testicular surface can be seen obviously and had high contrast with other tissue nearby, that's a reason we take it for specimen.

Tai Chieh Wu. National Taipei Univ. of Tech.
E-mail: djwu1224@gmail.com

PA signal is a convolution production includes tissue, media, laser pulses, ultrasound transducer and other noise. There are many methods have employed in photoacoustic tomography and signal processing such as filtered back projection (FBP), k-space of time reversal, deconvolution algorithm, fast Fourier transform in frequency domain and wavelet transform in time domain. In this paper, we demonstrate a novel filter method which is LMS adaptive filter to extract the PA signal from those collected signals with high SNR. The result shows a better image by using LMS filter. Further, the spatial resolution that finer than original reconstructed image than twice can reach 200 μm.

## 2. Experiment and Method

A representative circular-scanning PAT system is shown in **Fig.1**. The system integrates a tunable optical parametric oscillator (OPO) laser pumped by the double harmonic output of an Nd:YAG pulsed laser (Brilliant B, Quantel) as the excitation source. The laser is modulated to 710nm which has the maximum contrast between vessels and tissue of chicken testicular. The laser pulses, with a repetition rate of 10Hz and pulse width of 6ns.The PA signal was collected with a 10MHz ultrasound transducer (V327, Olympus) and amplified (5900PR, Olympus) into PC. The chicken testicular is placed in the water tank and illuminated by the expanded and homogenized laser beam. A rotational detection system that is driven by PC-controlled stepper motor scans the transducer around the specimen with a radius of 17.5mm and a step size of 1°. At last, a computer acquires the signals for image reconstruction.

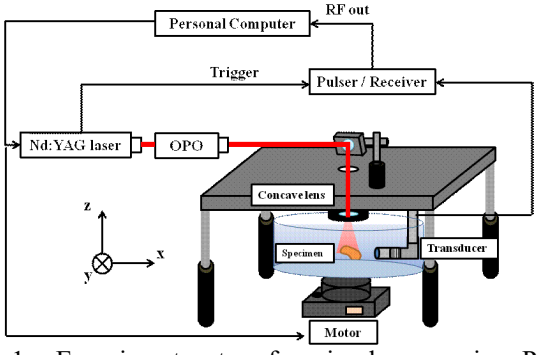


Fig. 1 Experiment setup for circular scanning PAT system

Signal processing plays an important role in this study. We use the LMS adaptive filter and Wiener deconvolution in order to extract the weak PA signal from other unnecessary signals and noise. The LMS algorithm are a class of adaptive filter used to mimic a desired filter by finding the filter coefficients that related to producing the least mean squares of the error signal. **Fig.2** is the flow chart of LMS algorithm implement in photoacoustic signal process. First, the algorithm calculates the output signal y(n) from the adaptive filter, and then, calculates the error signal e(n) by the relationship of d(n) and y(n). Third, updates the filter coefficient by using the following equation:

$$\vec{w}(n+1) = \vec{w}(n) + u \bullet e(n) \bullet \vec{u}(n) \qquad (1)$$

Where u is the step size of the adaptive filter, $\vec{w}(n)$ is the filter coefficient vector, and $\vec{u}(n)$ is the filter input. For our experiment, the step size u is 2.35, and the filter length is 256. **Fig.3** indicates the comparison of original and processed signal.

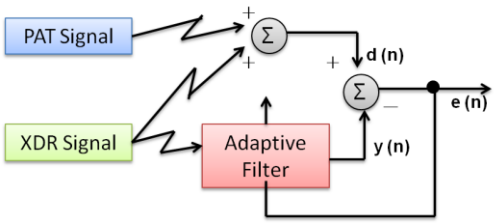


Fig. 2 Diagram of LMS algorithm.

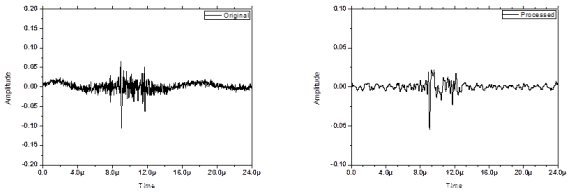

Fig. 3 Comparison between original(left) and processed(right).

## 3. Result

**Fig.4** shows a result of photoacoustic image for chicken testicular. By circular scanning, 2D image can be reconstructed with single element transducer. Relying on tissue's intrinsic optical absorption contrast, the vessels in the testicular are visualized clearly. On the other hand, due to the LMS adaptive filter we cannot only extract the signal from tissue without high frequency white noise but also receive precise image, as illustrated in **Fig.5**. According to result of LMS filter, the spatial resolution can reach about 200 μm. It's better than original image twice. In addition, employing this method doesn't cost more time in computing. It's convenient and efficient.

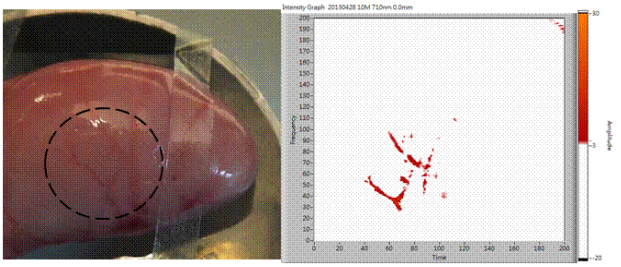

Fig. 4 Photoacoustic image for testicular.

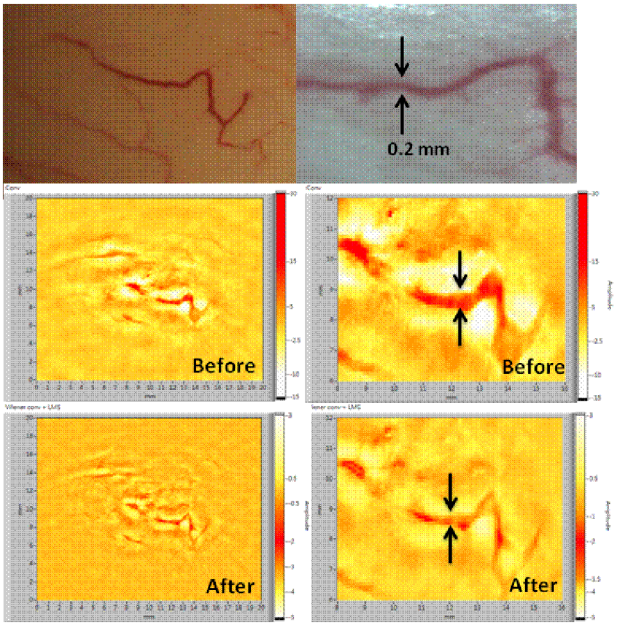


Fig. 5 Comparison between original photoacoustic image and processed image. The spatial resolution of original image is 400 μm. After LMS filtering, it can reach 200 μm

## 4. Conclusion

Our work has been demonstrated to be a potential non-invasive imaging method for studying living organs to various small animal models in biological and biomedical research.

## References

1. A. G. Bell, "On the production and reproduction of sound by light," *Amer. J. Sci.*, vol. 20 (1880), pp. 305–324.
2. Y. Xu, M. Xu, and L.H. V.Wang, "Exact frequency domain reconstruction for thermo acoustic tomography—II: Cylindrical geometry," IEEE Trans. Med. Imag., vol. 21 (2002), pp. 829–833.
3. C. Zhang, C.H Li, and L.H V. Wang, "Fast and Robust Deconvolution-Based Image Reconstruction for Photoacoustic Tomography in Circular Geometry: Experimental Validation" IEEE. Photonics journal., vol. 2 (2010), pp. 57-66.