Mobile-to-Mobile Communication for Lung Sound Auscultation: A Preliminary Study of Perspective on Auto-regression Model

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***Abstract*--This study employed the correlation coefficients analysis of time sequence, spectrogram, and auto-regression model of signals which were the lung sounds of subject end, and distant end where the sound was transmitted by mobile-to-mobile communication. The results presented that the correlation coefficients of time sequence, spectrogram, 4-order coefficients of auto-regression model were 0.36, 0.69, and 0.82 in the bell filtering mode, and 0.28, 0.69, and 0.81 in the diaphragm filter mode. Based on the high correlation coefficients of the spectrogram, and 4-order coefficients of auto-regression model, we believe that the mobile-to-mobile communication is a feasible method for distant lung sound auscultation.**

***Keywords*—mobile, communication, lung sound, auscultation, correlation, signal processing.**

I. INTRODUCTION

In the ordinary therapeutic and diagnosis procedures, the patents of heart or lung diseases, such as wheeze, hypertension, or heartache, go to the clinics or hospitals for medical doctors' auscultations periodically. However, the discomfort or absence of the patents occur unpredictably. A distant auscultation and recording system which functions as an auscultator or a listener is good at the diagnosis of the medical doctors to get the fresh information from the patents in their daily life. This enhances the lost information of the regular auscultations when the patents go to the hospital or clinics, and increase the precision or convenience of the medical doctors' diagnosis.

II. METHOD

In the statistical testing, the joint probability functions of the two random variables X, and Y are usually unknown. The correlation coefficient ρ, serves as a measure of the dependency between X, and Y. μ is the mean value, x, and y represented as the elements of X, and Y, respectively. Generally, the ρ>0.8 can be explained that X, and Y are highly positive dependent

A. Confidence interval

Statisticians usually employ a confidence interval to express the degree of uncertainty associated with a sample statistic. A confidence interval is an interval estimate combined with a probability statement. The confident interval was written as:

$$ci = 1 - \alpha \quad (1)$$

where α is the significance level. The most popular significant confident levels are 90, 95, and 99%. In this study, we checked α <0.05 to ensure the computed correlation coefficients are significant. [1-2]

B. Spectrogram

The element at the time τ in a spectrogram is defined as [7]:

$$|X_\tau(j\omega)|^2 = \left|\int_{-\infty}^{\infty} x(t)\,\emptyset_{\tau,\omega}(t)\,dt\right|^2 \quad (2)$$

where $x(t)$ is the signal in the time domain, $\emptyset_{\tau,\omega}(t)$ is the complex basis function, and $|X_\tau(j\omega)|^2$ is the power distribution in the frequency domain at the time τ. This form of the Fourier transform, also known as the short-time Fourier transform (STFT), has numerous applications in speech, sonar, and radar processing. The spectrogram of a sequence is the magnitude of the time-dependent Fourier transform versus time.

Many researchers of the heart and lung sound analysis employed the technology of spectrogram analysis to explore the characteristics of the heart and lung sounds, because the spectrogram presents the power densities in both of time and frequency domains [3-4]. It clearly shows the characteristics of the signals in 3 dimensional presentations.

C. 3M™ Littmann® Electronic Stethoscope Model 3200

The Model 3200's combination of Ambient Noise Reduction technology, frictional noise dampening materials, electronic amplification (conventional bell / diaphragm modes plus an extended range mode), Bluetooth® data transfer, and an all-new user interface takes you to the next level of performance and ease of use.

This electronic stethoscope allows the user to select between three different digital frequency filters to better emphasize the specific patient sounds of interest. (1) The Bell mode amplifies sounds from 20 - 1000Hz, but emphasizes lower frequency sounds between 20 - 200Hz. (2) The Diaphragm mode amplifies sounds from 20 - 2000Hz, but emphasizes the sounds between 100 - 500Hz. (3) The Extended Range mode amplifies sounds from 20 - 2000Hz similar to the Diaphragm Mode, but provides more low frequency response between 50 - 500Hz.

D.Autoregressive model

The AR model is a powerful mean for time series analysis. The AR time-series model is written as:

$$x(k) = -\sum_{n=1}^{p} a_n \, x(k-1+e(k) \qquad (3)$$

where k=0,1,2…, x(k) denotes for the samples of the modeled signal, a_n for the AR coefficients, and P for the order of the AR model and residual e(k) represents a white noise sequence. The AR coefficients are approached by taking the minimum of the variance of e(k) [5].

E. Mobile-to-Mobile

The picture of smart phones was presented in Fig. 1. We inserted a small-scale microphone attached to the ear set of a smart mobile (hTC™, Desire 620) into the ear tip of a stethoscope to transmit sound through the mobile when it dials and connects to another phone or mobile. We employed another smart phone (Samsung™, SM-360G) to serve as the receiver. If the receiver is embedded with a real-time recorder, such as a circuit or computer software, then the detected sounds can be stored for subsequent analysis [6,7].

III. RESULTS

In the bell filter mode, Fig. 2 presented the 6-second normalized signal, x(t), of the subject end transferred in to PC by Bluetooth wireless communication technology and the recorded signal of auscultation end, y(t), in the mobile. The sampling rate is 8KHz. The shape of waveform was different, and the $\rho = 0.36$ and α<0.05. Furthermore, the spectrogram is shown in Fig. 3. The spectrogram is a 2-dimentional visualization presentation of signals. The 2-dimentional correlation coefficients of the two spectrogram was 0.69 which showed a quite positive correlation. The coefficients of 4-order AR model of the signals in both subject and auscultation ends were presented in Fig. 4. The ρ of the coefficients was 0.82 with α=0.086.

In the diaphragm filter mode, the 6-second normalized signal, x(t), of the subject end transferred in to PC by Bluetooth wireless communication technology and the recorded signal of auscultation end, y(t), in the mobile. The shape of waveform was different, but the ρ=0.28and α<0.05. Furthermore, the spectrograms of x(t) and y(t) were similar in this 6 seconds. The 2-dimentional correlation coefficients of the two spectrogram was 0.69 which showed a quite correlation. The coefficients of 4-order AR model of the signals in both subject and auscultation ends were presented that the ρ of the coefficients was 0.81 with α=0.09(Fig. 5, 6, and 7).



Fig. 1. The smart phones: hTC™, Desire 620 as transmitter, and Samsung™, SM-360G as receiver.

IV. DISCUSSION

Because the sound usually occurs when the human body moves, the noise is not easy to reduce in this study. Therefore, we need to consider the influence of the environmental noise. However, the stethoscope can cancel the environment noise by the diaphragm. Therefore, though the environmental noise level occurred randomly, the correlation coefficients of all x(t) and y(t) were presented in a high positive cross correlation. The shorter duration tests will be studied in the near future [8].

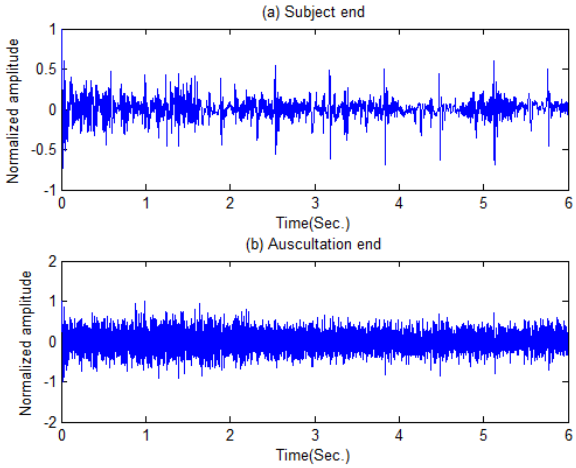


Fig. 2. Signals of mobile-to-mobile communication in bell mode filter: (a) Subject end, and (b) Auscultation end

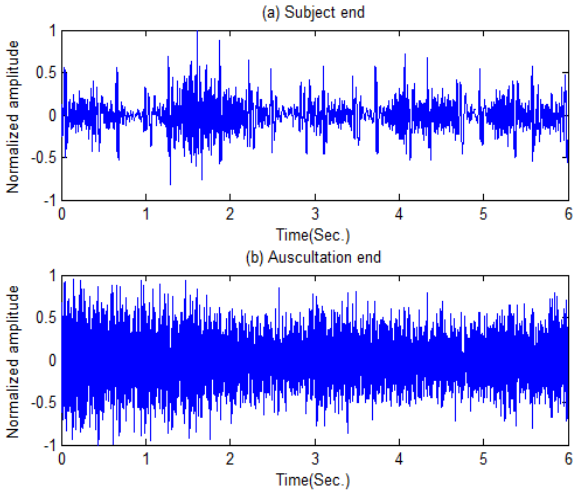


Fig. 4. Signals of mobile-to-mobile communication in diaphragm mode filter: (a) Subject end, and (b) Auscultation end

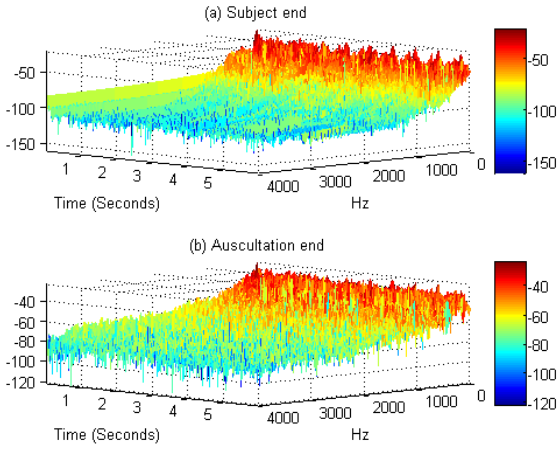


Fig. 3. Spectrograms of mobile-to-mobile communication in bell mode filter: (a) Subject end, and (b) Auscultation end

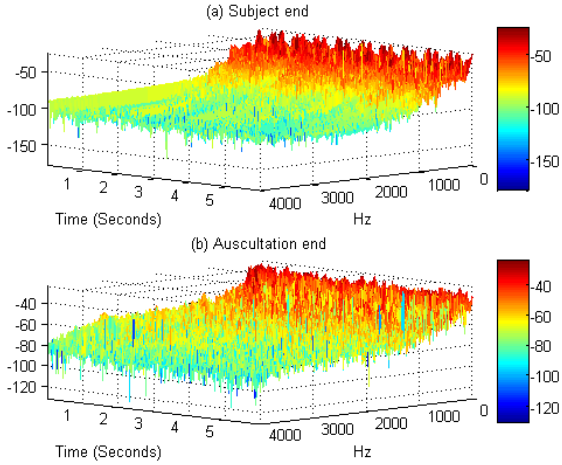


Fig. 5. Spectrograms of mobile-to-mobile communication in diaphragm mode filter: (a) Subject end, and (b) Auscultation end

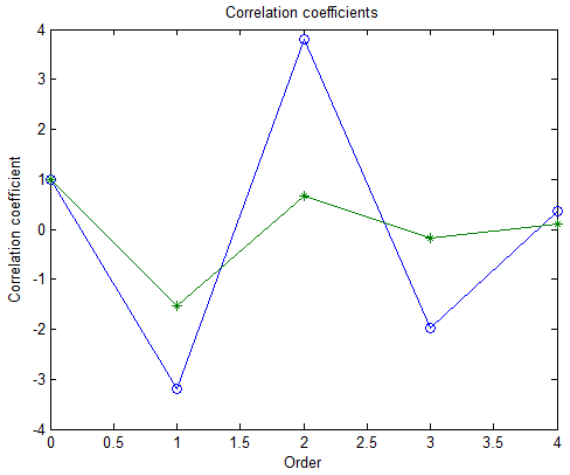


Fig. 4. Coefficients of the AR model in bell mode filter: (a) Subject end, and (b) Auscultation end

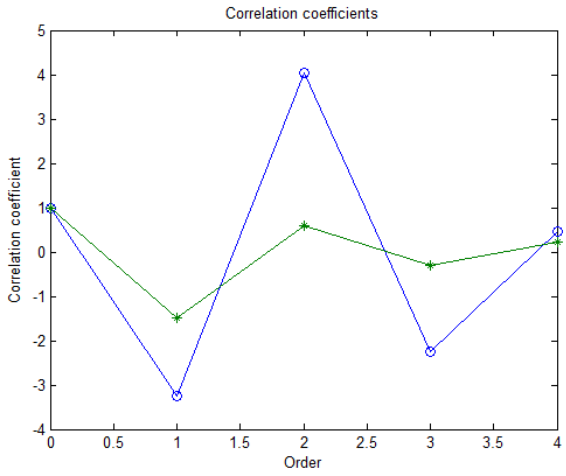


Fig. 6.. Coefficients of the AR model in in diaphragm mode r: (a) Subject end, and (b) Auscultation end

V.CONCLUSION

Based on the 3 methods of testing, we believe that the mobile-to-mobile communication is a feasible method for distant lung sound auscultation.

VI. REFERENCES

[1] M. Bahoura, "Pattern recognition methods applied to respiratory sounds classification into normal and wheeze Classes," Computers in Biology and Medicine, vol. 39, pp. 824-843, 2009.

[2] C. Kroen, "Back to the Bedside: The Art of Physical Diagnosis," The Hospitalist, pp. 1-39, 22 January/February 2003.

[3] S. Haykin, B. Van Veen, *Signals and systems*, Wiley, New York, 1998.

[4] L. C. Ludeman, Random processes filtering, estimation, and detection, Wiley, New York, 2003.

[5] G. C. Chang, Y. F.a Lai, "Performance evaluation and enhancement of lung sound recognition system in two real noisy environments", Computer Methods and Programs in Biomedicine, vol. 97, pp. 141-150, 2010.

[6] User Manual, Desire 620, hTC™.

[7] User Manual, SM-360, Samsung™

[8] M. Steven, Kay, Modern Spectral Estimation: Theory and Application, Prentice-Hall, NJ, USA, 1988.