A Study on Visualization of Auscultation-based Blood Pressure Measurement

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Abstract— **Blood pressure measurement by Korotkov sounds auscultation is an essential skill for health care workers, but the skill mastery is not easy because complicated tasks such as simultaneous auscultation, manipulation of pressure, and checking of scale are required. This work provides a system to visualize the Korotkov sounds and pressure-in-cuff by sensing them at the same time. Plus, we evaluate the system from the viewpoint of an educational assistance of the skill mastery of blood pressure measurement.**

I. INTRODUCTION

In recent years, due to the aging of society, with a growing demand for human resources of doctors and nurses, there is an increasing requirements of the medical support system for the human resource development.

In auscultation-based Blood Pressure, nurses are requested to do complex tasks, pressurizing and depressurizing, auscultation and visual recognition at the same time. Plus, they must hear "sounds" that are dependent on the sense of the individual. In the actual education, a bifurcated stethoscope is used to share the Korotkov sounds by lecturer and nurse student and the lecture gives guidance while listening to the same sound. But, this style of the education has many problems such as inefficiencies and guidance difficulty of timing, the difficulty of iterative learning. In the traditional way, these skills are used to be accumulated as know-how in clinical practices, but opportunities for skills improvement is low due to the spread of electronic sphygmomanometer to clinical practices. In order to grasp the condition of urgent patients, an electronic blood pressure meter is not available, an auscultation method is still necessary.

In this work, for the purpose that nurse students acquire the know-how of the auscultation method, we provide a sensor system to visualize the pressure and Korotkov sounds within the cuff to hear from stethoscope in real time. A lecturer and a nurse student can share the process of measurement while watching the same screen. The nurse student can carry out the review of the study using this system. For realizing the proposed system, it is necessary to work in the software for extracting the signal processing by Korotkov sounds auscultation as well as developing a hardware along with sensors.

II. KOROTKOV SOUNDS

An auscultation-based blood pressure measurement is well known fundamental nursing skill (auscultation), the difficulty of the mastery is in fact high. In the auscultation method, the artery is clamped by the cuff (arm band) to stop the flow of blood and pulse sounds (Korotkov sounds) within the blood vessel is measured by using a stethoscope to occur when subsequently

deflated. The blood pressure is called systolic at the beginning of the pulse sounds to hear, while the blood pressure at the disappearance of the pulse sounds is referred to as diastolic. Fig. 1 shows the relation of Korotkov sounds curve and pressure in the cuff in auscultation.

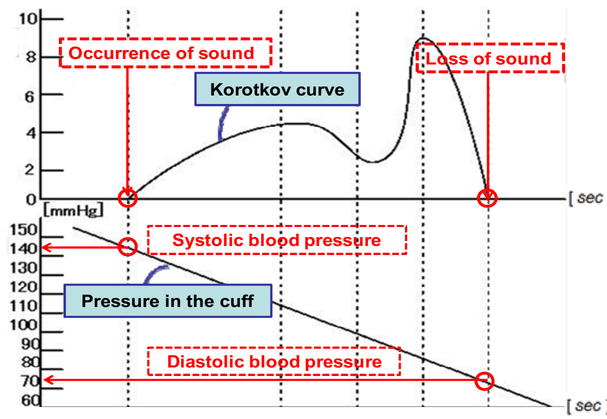


Fig. 1. Korotkov sounds and pressure in the cuff

III. PROPOSED SYSTEM

Fig. 2 demonstrates the overview of our proposed system for education of nurse students by visualizing the process of blood pressure measurement. The system is composed of a sensor board connecting the stethoscope and a tablet for displaying the measurement result. On the sensor board, DPS module is implemented for signal processing.

This work focuses on a signal processing technique for removing noise from the Korotkoff sounds obtained by the stethoscope. In the signal processing in the frequency domain of audio acquisition, we attempt to remove only the signal with a large power spectrum of the medium and high frequencies.

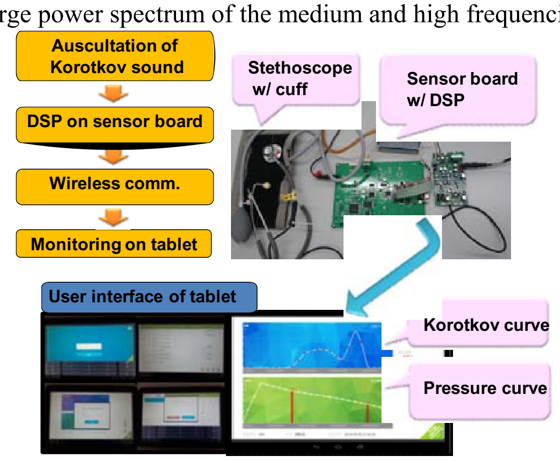


Fig. 2. Overview of the proposed system

Fig. 3 shows the block diagram of our sensor board which is extended from ECG signal measurement board. The board has 8 channels for input signals and we use two of them, one is for sensing the pressure in the cuff, and the other is for sensing sounds in the the stethoscope. In addition, programmable AMP, ADC, DSP, FPGA, and wireless modules are integrated into the board.

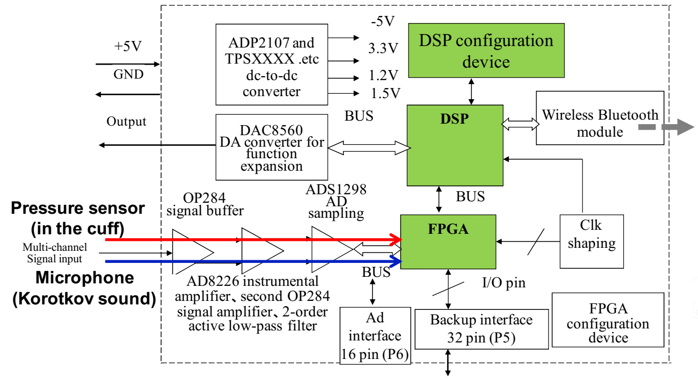
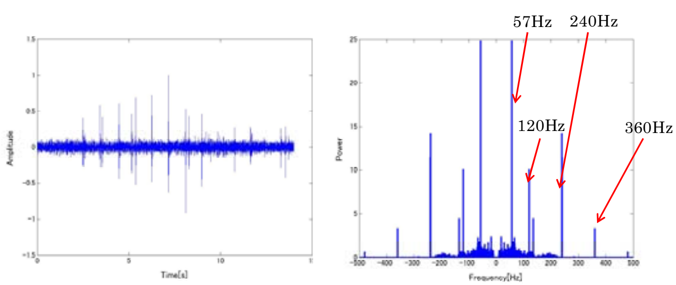


Fig. 3. Block diagram of ECG-based sensor board

IV. Adaptive Filter for Noise Canceling

In the work, we adopt an adaptive signal filter widely used as a noise canceling technique of acoustic equipment [1]. The system generates a pseudo signal of a specified frequency, dynamically adjusting the filter coefficients, it subtracts Korotkoff sounds from the acquired sounds to remove the noise by using an adaptive signal filter. Then, interpolating the extracted signal to create the Korotkoff sounds curve on a time axis, we calculate systolic and diastolic blood pressures.

Fig. 4 shows examples of Korotkov sounds and the power spectrum. In the spectrum, we can indentify several noise spectrums such as 57Hz, 120Hz, 240Hz, and 360Hz.



Korotkov sound   Power spectrum

Fig. 4. Acquired sounds of Korotkov sounds and power spectrum

We implement an LMS active filter in the MATLAB [1], and apply the filter to experimentally acquired Korotkov sounds. The resultant spectrums are shown by red color in Fig. 5. We can see obviously decreasing the noise specturms.

Plus, Fig. 6 shows audio signals before and after filtering. Even in the signal after filtering, there are some noise, but it is smaller compared to that in before filtering. It is significant that deacrease of the noise around the bias directly contributes to accuracy of calculation of systolic and diastolic blood pressures because they corresponds to crosspoints to the bias.

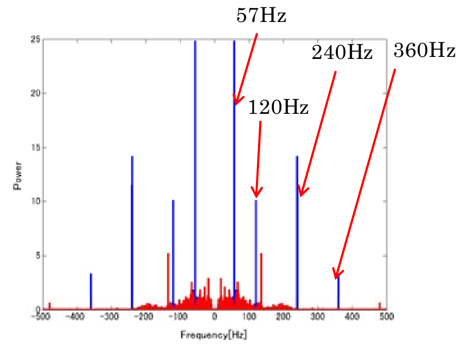
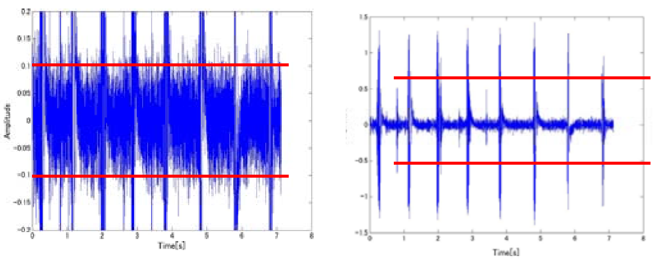


Fig. 5. Resultant spectrum by LMS active filter



(a) before filtering   (a) after filtering

Fig. 6. Comparison of Korotkov sounds before and after filtering

We experimented to measure the blood pressure before filing and after filtering. The experimental results are shown in Table 1. The errors are obtained by comparison with a nurse lecturer. By applying our adaptive filter, we could improve the error significantly.

Table 1: Error of blood pressure induced by Korotkov curves

	Time at systolic blood pressure (s)	Error in terms of pressure (mmHg)	Time at diastolic blood pressure (s)	Error in terms of pressure (mmHg)
before filtering	1.805	0.556	9.885	4.232
after filtering	1.944	0.278	10.943	2.116

V. Conclusion

In this work, we proposed a blood pressure measurement visualization system to support the learning of blood pressure measurement skill by auscultation. In the system, the sensor board acquires the Korotkov sounds and the pressure via a microphone and a pressure sensor, respectively. Plus, the DSP performs signal processing for noise canceling and the resultant waveform is transmitted to the tablet for displaying. We adopted the LMS adaptive filter for noise canceling, and demonstrated an improvement for measurement blood pressure values by filtering. Besides, we are convinced this visualization system is useful from the viewpoint of an educational assistance of the skill mastery of blood pressure measurement.

References

[1] Simon Hay kin, Adaptive Filter Theory , Prentice Hall, 1993, pp.50-56.