Automated Applied Pressure Control for Acoustic Signal Analysis with an Electronic Stethoscope

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***Abstract*— The ubiquitous stethoscope has been used mainly as a qualitative diagnostic tool. For quantitative analyses, how much pressure applied to the interface between the stethoscope probe and the skin could affect the signal properties such as the frequency spectrum. In this study a device has been developed to control the applied pressure of an electronic stethoscope automatically. An embedded control system ensures that consistent and repeatable acoustic data can be recorded at an optimal pressure. Preliminary results have shown that the device is capable of recording breathing sounds with consistent frequency spectrum over multiple trials. Furthermore, the recorded frequency spectra are sensitive to the applied pressure. Thus, this device should provide a useful tool for quantitative analyses of acoustic signals recorded from the human body.**

***Keywords*— stethoscope; applied pressure; pneumatic control; embedded system; acoustic signal analysis; frequency spectrum**

I. Introduction

One of the on-going research projects at the University of Rhode Island is to study the breathing sounds related to sleep disorders such as obstructive sleep apnea. Sleep apnea is characterized as breaks in the breathing patterns or shallow breaths during sleep [1]. Data suggest that up to 5% of adults are affected by this chronic disease [2]. Current tests for sleep apnea require a patient to stay overnight in a sleep lab and take a sleep test called a polysomnogram. One of the main problems with the polysomnogram is the time required to obtain the data [3]. Thus, our on-going research explores alternative methods such as signal analyses of the breathing sounds recorded with an electronic stethoscope. However, one of the problems that have surfaced is the lack of standardized pressure applied to the stethoscope probe, which could cause significant variations in signal properties.

The system developed in this study utilizes an electronic stethoscope to record the patient's breathing sounds. In order to obtain useful and repeatable data, a constant pressure must be applied to hold and maintain the pressure on the stethoscope probe. An automated applied pressure controller is designed to maintain a preset constant pressure. This paper describes the design and shows preliminary data of frequency spectra of breathing sounds recorded at the suprasentral notch.

II. Methods

A. Design Approach

As shown in Fig. 1, this device was designed to incorporate a constant source of pressure for stabilizing a hands free stethoscope that produces consistency when recording breathing sounds at the suprasentral notch. A harness was developed to allow the stethoscope to be placed within the same region of the body for different patients. Attached to the harness is a neoprene bladder, which is inflated to improve contact between the patient and the stethoscope. The automated pressure system is controlled by an embedded microprocessor (PIC18F4525, Microchip, Chandler, AZ). The processor reads an input voltage from the pressure sensor to and drive a pneumatic pump to inflate or delate the bladder until the desirable applied pressure is reached.

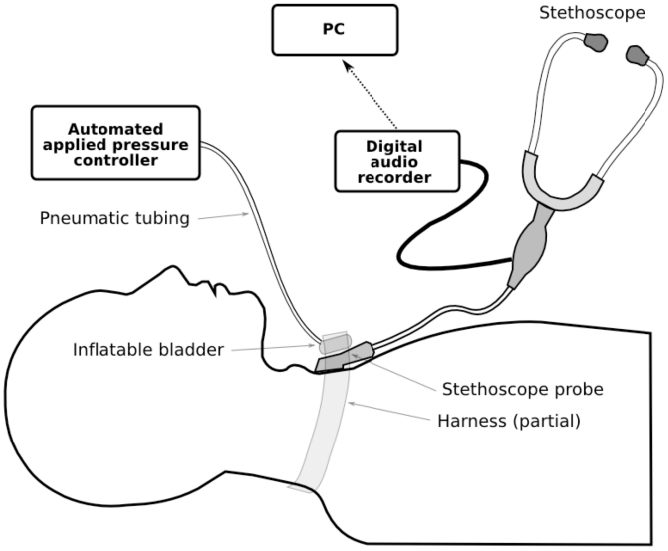

Fig. 1. Schematic diagram of the instrumentation of recording breathing sounds with an automated applied pressure controller.

B. Measurement Harness

The harness is made of several components that were modified to work together. The main component is the *Confor Clavicle Brace*. The brace consists of two shoulder straps that connect around the back and can be adjusted by Velcro. Attached to the brace is a neck strap that includes a buckle and Velcro. The neck strap spans across the patients suprasternal notch to hold the bladder on the stethoscope and to hold the stethoscope in place. The Jabes Electronic Stethoscope is used in conjunction with a H4N digital audio recorder during the test trials to record the breathing sounds. There were three different preset pressures that the bladder was set to. At each pressure breathing sounds were recorded for 20 seconds. There was also a trial conducted holding the stethoscope by hand. These sounds are then analyzed by using MATLAB's fast Fourier transform (FFT) function to determine the frequency spectra. The four different tests trials

were conducted three times to compare for consistency.

C. Automated Pressure Controller

In order to inflate the neoprene bladder, a system controller was developed to apply consistent pressure. With a custom microprocessor circuit, the air pressure is applied via the pump. A release valve is also included in the peumatic system. The valve is a voltage controlled solenoid that closes when a voltage is applied. In order to activate the pump and the valve properly a separate power source was engaged by the system via a MOSFET switch. An air pressure sensor is also utilized on the same tubing to read the back pressure from the bladder. This will give us an estimate of the pressure between the stethoscope and the skin. To adjust the pressure there are 3 push buttons, each with their own function.

The software allows for 3 push button interrupts, a timer interrupt, a display, 2 digital outputs, and an analog input. The primary button's function is to turn the motor on until a preset pressure is achieved. Each time this is pressed it increases to a higher preset pressure (3 levels) until the maximum level is reached. The second button does just the opposite. By pressing the decrease button the solenoid opens until the air pressure is decreased to the level below the current. The third and final valve has 2 functions. The first is an emergency release valve, and the second is to release the pressure after all the tests have been completed. The timer interrupt constantly checks to see if the pressure has reached a critical level (in case of system failure) and will turn the motor off and open the release valve if that level is exceeded.

III. Results

Figure 2 displays the frequency spectra obtained with three different settings: hand held, lowest setting, and highest setting of the automated applied pressure controller. For each setting the recordings were done twice to evaluate their consistency.

IV. Discussion

From Fig. 2, it can be determined that there is consistency in the trials involving the automated pressure device. Each trial was done 3 times and recorded randomly to ensure that there was the data was not skewed. In the hand trials, the spectral analysis shows some variations (arrows in Fig. 2), which is exactly what this project was designed to remove. As for the automated pressure device, it is shown that there is an improved element of consistency when each test is compared. However, on the first test trial there was an interference that came from an electromagnetic hum produced from the wire going to the recording device. By applying an electromagnetic shield, the noise from the source was reduced to a negligible. This design will be integrated into the box when the device is moved from the breadboard onto a protoboard. The first peak in each of the graphs represents an extremely low frequency pulse determined to be the heartbeat of the patient. This leaves the rest of the spectrum to be the different frequencies that make up the breathing sounds.

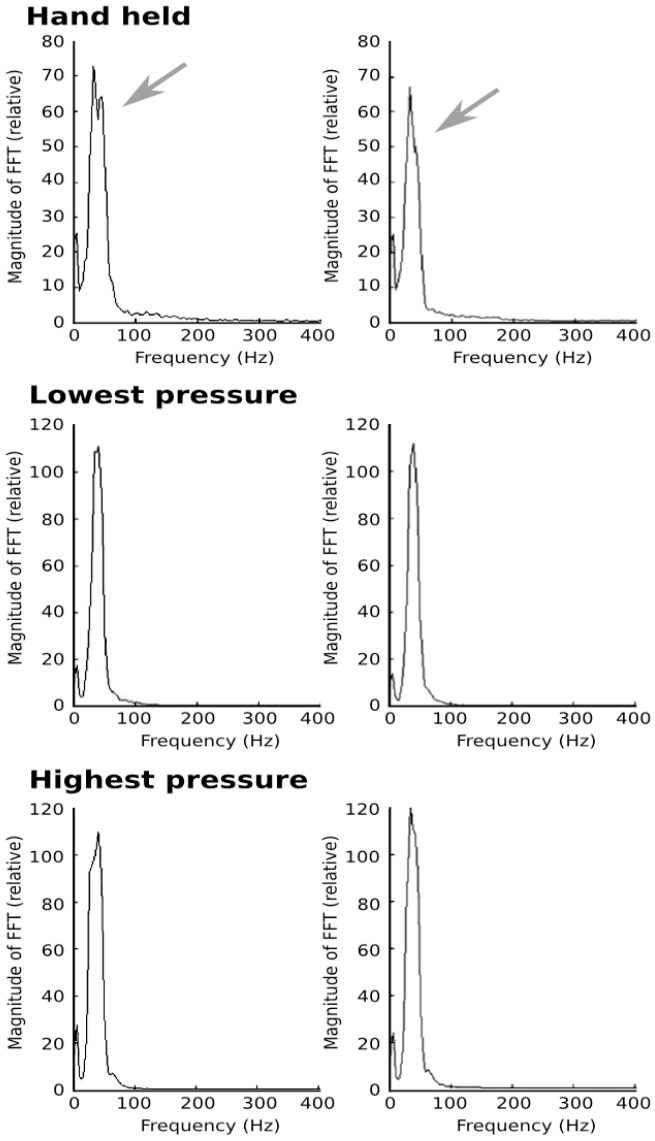

Figure 2: Comparison of two trials for hand held (top), lowest setting (middle) and highest setting (bottom) with the automated controller.

In the future, an IRB approved study will be conducted to provide a formal evaluation of the device with 20 human subjects. Each subject will undergo a hand held and device test. Both body mass and height will be recorded as well, this will help show that the device will give a consistent pressure no matter the BMI of the subject. When all parameters have been determined, the pressure values can be calibrated to improve the next round of trials.

References

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