Development of Computerized Recording Channel of Lung Sound

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Abstract—**Lung sound (LS) records are first stage of studying breathing diseases and indicate the lung function performance. This paper gives a developing method that records LS using a computerized channel. It discusses the chosen components of this channel that reduce noises. Other purpose of this paper is to provide detailed discussions of the issues concerning digitization and sampling frequency of LS records. The method of recording LS includes two trends: developed hardware and created software. Hardware part ends in analog-digital input of sound card with ADC 16 bits. Software includes displaying LS using created program by Graphical User Interface (GUI) MATLAB. It provides LS record in wave data with 44.1 kHz sampling frequency and converts it to 11.025 kHz sampling frequency for future analysis. The developed computerized recoding channel of lung sound (CRCLS) achieves sensing, capturing, recording, displaying, converting and storing LS records.**

Index Terms—**Lung sounds, LS records, COMPUTERIZED channel, sampling frequency.**

I. INTRODUCTION

The stethoscope is an acoustic medical device for listening to internal sounds in human body which is known, in medical terms, as auscultation. The French physician Rene Laennec, fashioned the first stethoscope by rolling a sheet of paper into a cone in 1816. After realizing that the quality of the sound was better than that obtained by direct auscultation, the stethoscope began to appear much the same as it does now, with a binaural design, flexible tubing, and a rigid diaphragm[1]. A comparison of six different stethoscope models in 1992 examined the transfer function of the instruments for sound frequencies between 37.5 and 1000 Hz and demonstrated that, in most cases, low-frequency sound (37.5-112.5 Hz) was amplified by bells and attenuated by diaphragms[2]. Most of the modern stethoscopes remain simply a conduit for sound's more conditions between the body surface and the ears with an inherent feature in their design that amplifies sounds below 112 Hz and attenuates higher frequencies. Even with the evolution of the electronic stethoscopes that provide higher amplification and selective different ranges of frequencies, the factors of limitation of the human ear and the subjectivity of interpretation remain as major obstacles in the lung sound analysis. Over the past 20 years, computerized methods for the recording and analysis of respiratory sounds have overcome many limitations of simple auscultation [3].

Improvements in electronic recording and the development of computer-based methods have made quantitative studies of lung and tracheal sound signals possible as well as overcome many limitations of a human ear subjective auscultation. Computerized respiratory sound analysis can quantify changes in lung sounds, de-noise the signals of interest from any artifacts and nosiness; store records of the measurements made, and produce graphical representations of the characteristic features of the respiratory sounds to help with the diagnosis and treatment of patients suffering from various lung diseases [4]. Nowadays, it appears the term of electronic auscultation, which is an efficient technique to evaluate the condition of respiratory system using lung sounds. Computerized Recoding Channel of Lung Sound (CRCLS) used to include only LS that are accepted from respiratory sounds, which include in it sounds of all organs of breathing system. Lung sounds give information indicate the lung function performance by recording from an anterior (chest) and posterior areas. For the definition of different kinds of sounds, an attempt has been made to make clear distinctions between adjectives indicating locations like lung, trachea, etc.[5].

The rest of this paper is organized as follows. Section 2 presents components computerized channel and the discussion of their work together. Section 3 presents the methodology and software that is used to capture LS using created program in Graphical User Interface (GUI) program in MATLAB. Section 4 presents LS recorder program and its possibilities. Section 5 presents the conclusions and future work.

II. CRCLS DEVELOPMENT

One of the most non-invasive promising methods for LS and measurement of other respiratory function parameters is recording. This is an indirect measurement method leads to system, which automatically collects and analyses primary physiological data. Many ways are used to record LS by different instruments such as one microphone from one place of the body or many microphones from different places. Another use electronic stethoscope, MP3 with recording sensor and so on [6], [7].

CRCLS is a developing channel from Al-Naggr's work [8] and the development includes the following trends:

- Electronic part processes imperfections such as reducing noise by determining microphone position and add Butterworth band-pass filter which will be discussed in related part in this paper.
- Software part replaces processing of the LS in Adobe Audition, Excel and some tools in MATLAB by

created GUI based MATLAB program, which collect some processing (will be discussed in section 3) of LS in it.

The developing channel, CRCLS, consists of two parts, analog and digital part, as shown in Fig. 1. The analog part consists of stethoscope bell, an electret microphone, these two components work as a sensitive element.
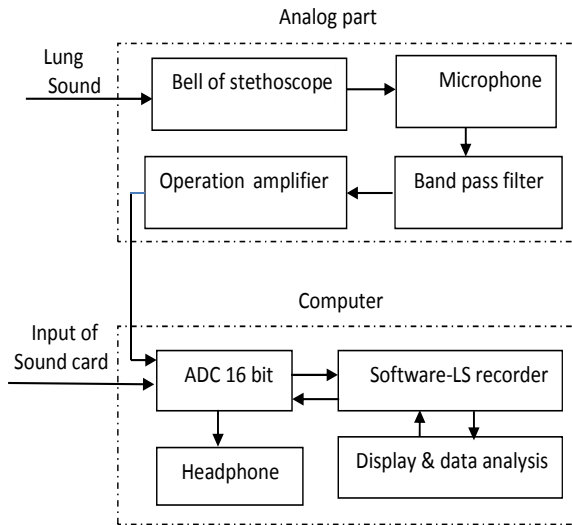

Fig. 1. Block diagram of CRCLS

The stethoscope bell is used without diaphragm to be placed on the skin during recording process. An electret microphone placed in tube which connected between microphone and cup of stethoscope bell in distance 5-10 cm to reduce noise of created interior the cup of stethoscope bell. This solution was taken as a result of experiment and expert advice. In experiment, the microphone was placed in a cup of stethoscope bell and recoded many LS after lung sounds were recorded, putting microphone in different distance from cup as shown in Fig.2. The comparison between those sounds was clarified that putting the microphone in a distance from the cup is better on resolution and reducing noise.

An electret microphone (Ecm-150 Sony) applies the condenser principle in such a way that its output voltage is proportional to the displacement of its diaphragm. The microphone is selected with:

- Frequency response 50 – 15000 Hz.
- Sensitivity: open circuit output voltage level -45±3 dB, and effective output level -55±3 dB.
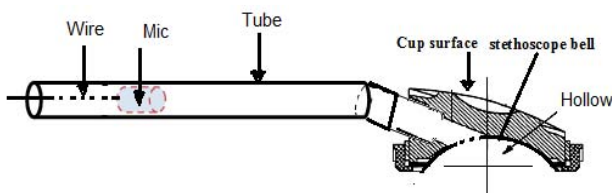- Maximum sound pressure : input level (at 1000 Hz , 1% distortion)

Fig. 2. The components of sensitive element

The next element shown in Fig.2 is band pass filter Butterworth with cut off frequency of about 103 Hz to 1 kHz to hear lung sounds. The filter followed by operation amplifier. This amplifier (LM386) is audio power amplifier and its IC is with built-in biasing and inputs that are referred to ground. It has a gain of 20. Any amplifier is described by

its frequency bandwidth, noise and dynamic range. These features had given as rules to record LS in Vaitkunas work[6]. It can drive any type of headphones including low impedance, which means 8 Ohm. All elements that have stated above considerate the analog part of CRCLS.

The second part of CRCLS is a digital which began by input of sound card of computer. Any sound card includes an analog-digital converter (ADC) to digitize the signal, audio signal of LS in this case, Digital input/output (DIO) subsystems are designed to input and output digital values. These values are typically handled either as single bits or lines, or as a port, which typically consist of eight lines. In this case, the sensor signal is a voltage level that is proportional to the physical phenomena of interest.

As a result of measuring bio-signal, there are two cases, measuring slowly is changing, which called quasi-static bio-signal like temperature, a slow sampling rate usually suffices, but if the measuring is rapidly changing, which called dynamic bio-signal like vibration or acoustic measurements, such as LS, a fast sampling rate is required. From this point the record done with sampling rate frequency 44.1kHz . However, there are clear advantages in adopting sub-multiples of sampling rate 44.1 kHz. Many researchers have been using such standards to record LS [9].

In addition, there are strong reasons for adopting a standard of 16 bits for the ADC resolution. With highly accurate equipment, this allows a 59 dB dynamic range. It is recommended [9] that the 16-bit samples be stored as follows: two bytes per sample, each pair of bytes representing a 16-bit signed integer in the range -32,768 to 32,767. The least significant byte is first, followed by the most significant byte 16-bits "two's complement" form, is used for the 16-bit signed integer. Generally, to make high-quality measurements during work on CRCLS, the rules below should be followed:

- Maximize the precision and accuracy.
- Minimize the noise.
- Match the sensor range to the A/D range.

Finally, in the analog part more concern was tended to reduce noise. Noise is considered to be any measurement that is not part of the phenomena of interest. Noise can be generated within the electrical components of the input amplifier (internal noise), or it can be added to the signal as it travels down the input wires to the amplifier (external noise). Reducing noise was processed in this part in two positions as the following:

- Putting Mic inside the tube in distance 5-10 cm to reduce noise of created interior the cup of stethoscope bell as state above.
- Using band-pass filter Butterworth with cut off frequency to remove internal noise.

III. CRCLS SOFTWARE

There are many methods that are used to capture and process LS with different purposes using simulation program as neural networks, MATLAB and so on. These simulation programs used for signal processing and analysis LS. Same organizations built on line date bases of LS records as the

R.A.L.E. used by others [10]. On the other hands, same researchers and organizations are working in this trend created own system which included recording hardware and processing software of LS for purpose of studying and analysing both LS and respiratory sounds [11][12]. Created CRCLS considerate an initial system for the future work, so simulation software program is created in Graphical User Interface (GUI) in MATLAB. It was used for many advantages such as universal idea of icons, buttons, math mediator and etc., that are visually presented to a user as a front-end of software application. The built program was called LS Recorder and this program was organized according to a flow chart shown in Fig.3. Flow chart clarifies association between analogue part of CRCLS and software, and link into the same program. The front created window includes the main menu (File, Edit, … etc.) capable to many editor process. The program includes other additional buttons as follows:

- Button " Record" used to record LS and display in real time. This test program was created to deal with capturing signal of LS record concerning with sample frequency 44.1 kHz to give digital record combined with 16 bites. It displayed a wave form of LS record with duration on axes x in time or sample as shown in Fig.4 .
- Button "Convert": this button used to convert LS record from 44.1 kHz to 11.025 kHz. This step is made as a point of view for next work. Button "Clear"- this button used to remove previous record from memory and display.
- Button" Exit"- this button used to exit from LS Recorder program.

IV. RESULTS AND DISCUSSION

Procedures of CRCLS are examined for verifying channel work with the developed based program. The CRCLS made as one model and subject to more experiences as possible. The details of CRCLS for each element was required to get quality record. The parts that have taken more concern are a type of stethoscope bell, choose microphone, place of microphone related to stethoscope bell, filters (With property range), and features of digital part (sound card). LS records have been taken according to the position of auscultation sites, using this channel, for 10 sec at each site, as the following order of placement: front top left and right, fronterolateral bottom right and left, back top right and left and back bottom left and right. Recording will be performed at the participant's normal breathing patterns during recording without being asked to take deep breaths.

The features of LS records are wave form sound and universal 44.1 kHz sampling rate which standard for digitizing of pulmonary sounds. Recording with those characteristics does not waste the digital storage and perhaps, more importantly, the processing capacity for many
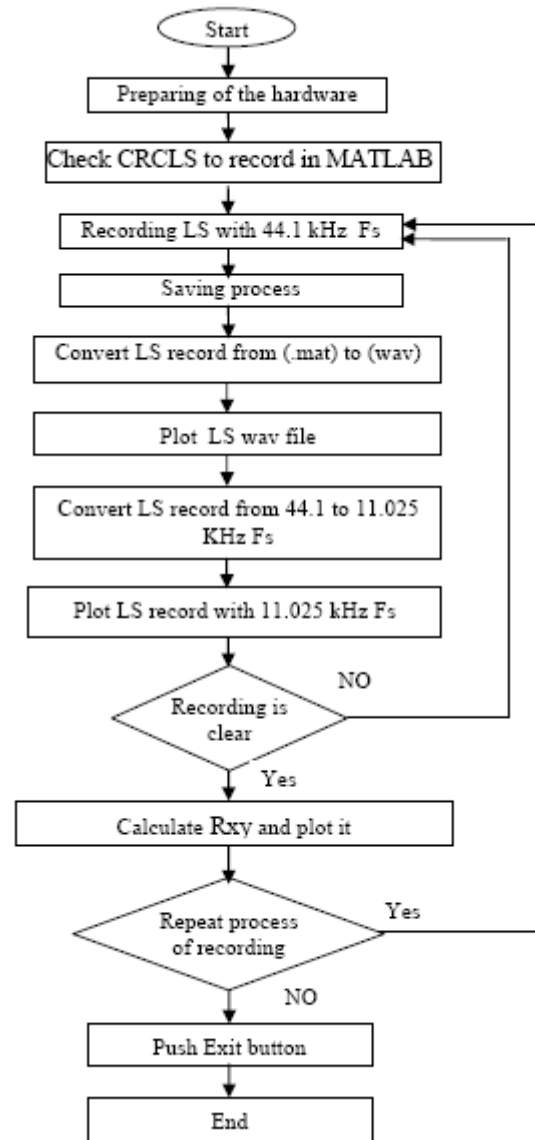

Fig. 3. Flow chart of software program LS recorder

Applications and for converting to another sampling rate is lower than 44.1 kHz. Hence, recording in this program is combined with two parameters, which are wave form sound and 44.1 kHz sampling frequency. The needs for the future process, LS record was converted to 11.025 kHz sample frequency because analysis with 11.025 kHz is simpler than 44.1 kHz. In general, there is a need to convert wave file to make file (LS record) simple for analysis. On the other hand, recording (from beginning without converting) with the 11.025 kHz sampling, any input signal content above 9.025 kHz will cause aliasing in the frequency band 0 Hz to 2 kHz. This signal content must be effectively removed by an "anti-aliasing" low-pass filter before digitization. If the anti-aliasing filter is an analogue low-pass filter with 3 dB cut-off frequency at 2 kHz, and at least 24 dB attenuation is required for any aliasing. The order of the filter can be as low as two. A forth-order Butterworth low-pass filter with a cut-off frequency of 2 kHz would give 52 dB attenuation at 9.025 kHz.

The main purpose of this paper is to create computerized digital channel, so view LS records using GUI MATLAB was as test of CRCLS working as shown in Fig.4. From this point, the processing was not applied in LS records. Getting point of view of LS records has shown a correlation of signals to note approximated wave of signals in case with different sample frequency and types of LS records (normal or abnormal).Those functions allow to get very primary information about LS signals. In the same figure shown LS record from back-left side of spin, this LS record is shown with 44.1 kHz and 11.025 kHz after converting to compare.
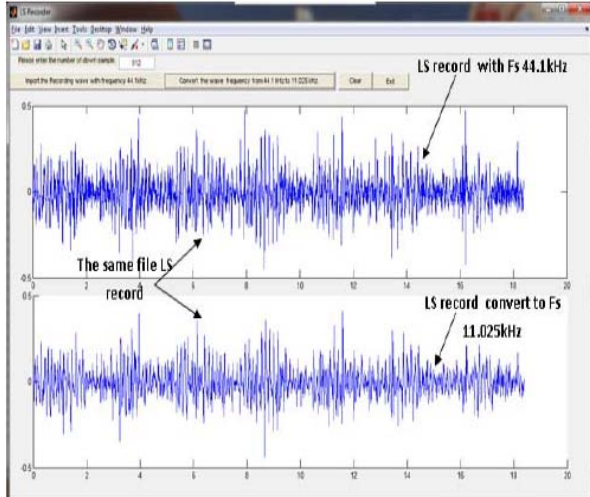

Fig. 4. The main window of LS recorder

V.   CONCLUSIONS AND FUTURE WORK

There are many methods to record digital data of LS and with CRCLS. The process is simple to record LS by knowing the components of this channel and its sequence. This paper shows that there are many options to use components and methodology to record LS. However, there are many variations in the details of LS capture among researchers, which make comparison of results is different. A clear description of CRCLS is essential to practice recording of LS and to know the details of the issues concerning digitization of LS recordings. Present details of sampling frequency associate with selection next step of LS processing and analysis. Design of CRCLS as analogue and digital parts and LS Recorder program make an integrated mediator for the future analysis and this step attempts to do a universal instrument with individual processing program in the future.

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