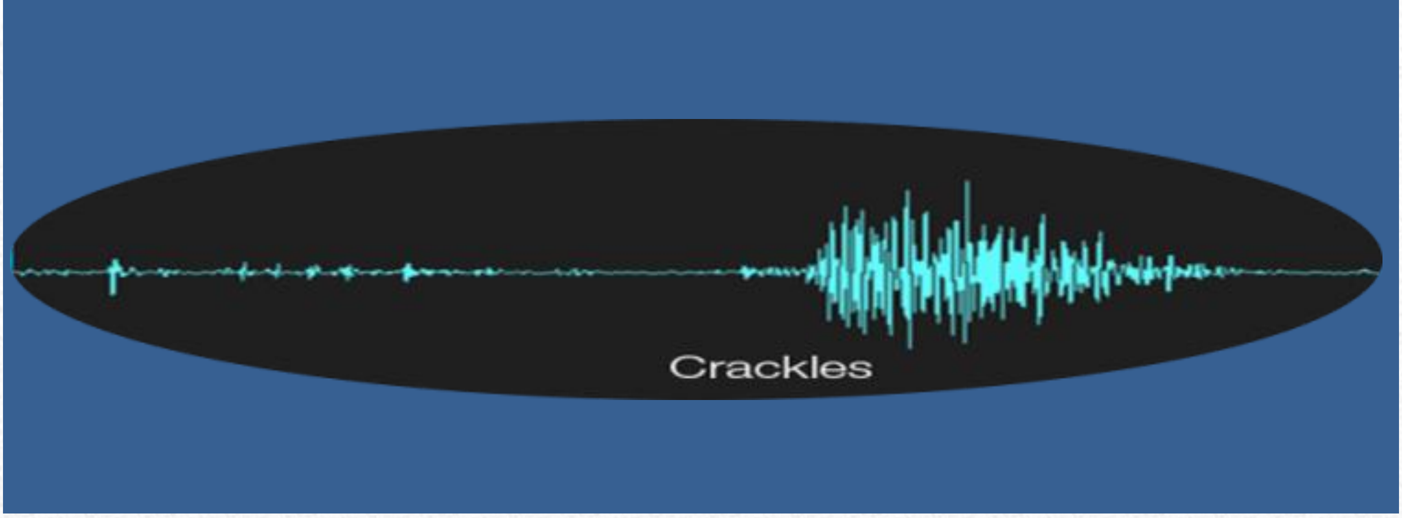

RLC-S

Recognition and Localization of a Crackle Sound

Providing a clinical tool for assessing in crackle sound detection in a respiratory physiotherapy for Cystic Fibrosis Patients

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Problem Definition:

The respiratory physiotherapy is one of many treatments that Cystic Fibrosis [1]patients need as a daily routine.

Its implementation basically depends on the recognition and localization of a crackle sound. Crackle sound is a lung sound provides useful information for assessing and monitoring respiratory patients.

The recognition and localization of a crackle sound considered as a serious obstacle for an experienced treatment.

Since the respiratory physiotherapy considered as the main treatment for easing breathing for CF patients, and also the number of CF patients have increased markedly over the last few years, hence, there is a great need for devising a clinical tool to guarantee an efficient treatment.

Background:

Cystic fibrosis (CF) is the second most common life-shortening, childhood-onset genetic disease.

One of the main CF symptoms is the chronic cough and great accumulation of phlegm in the airways and thus cause clogging in the airways.

In addition, the accumulation of phlegm in the airways causes unusual noise called crackles.

[1] A hereditary disease that affects the lungs

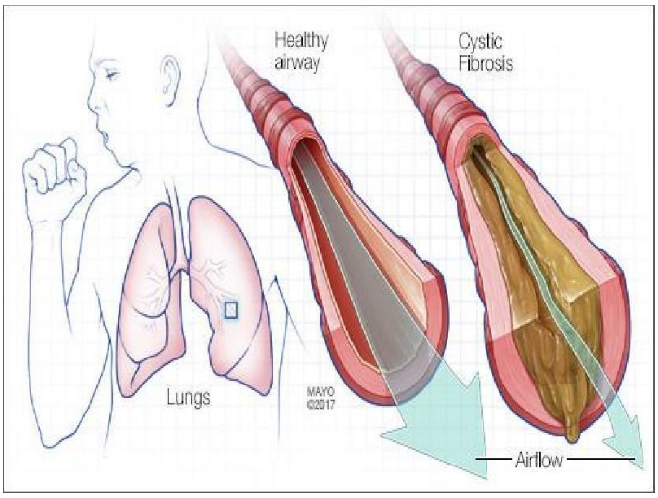


Figure 1: Airways Blockages

Respiratory blockages caused by this disease can be treated by draining the secretions by respiratory physiotherapy. This kind of treatment is one of the daily treatments that CF patients have to receive.

Respiratory physiotherapy is an airway clearance technique to drain the lungs.

As a first step, the physiotherapist must locate the place of the crackle.

During the treatment, the physiotherapist helps the patient to remove the secretions out by specific postures of breathing and pressing on the location of the crackle.

Therefore, the process of locating the exact place of the crackle is highly crucial.

As a try to simplify the diagnosis process, an electronic stethoscope was suggested.

Unfortunately, this stethoscope can offer just the signal plot after the recording process was done for the sound that was received when it was located in a specific area in the patient upper body, which can provide easy visualization and editing for the recorded signal.

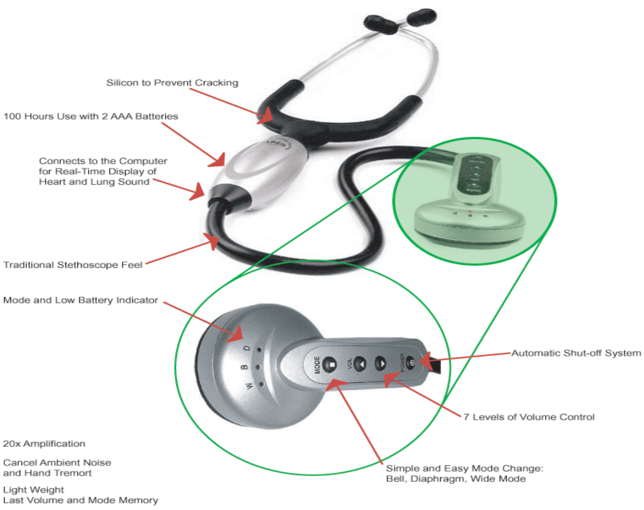


Figure 2: Electronic Stethoscope

Related Work:

Diagnosing disordered lung sounds brought up many years ago aiming to automatize the process.

As the crackle sound considered as one of these abnormal lung sounds, many diagnosing techniques were suggested beside factors that can distinguish a crackle sound from another.

Starting from the frequencies, normal breath sounds are noises with frequencies generally between 200 and 600 Hz while crackles are a sequence of explosive, nonmusical, interrupted pulmonary sounds with a wide spectrum of frequencies between 200 and 2500 Hz.[2]

Crackles also characterized by their specific waveform, their duration and their location in the respiratory cycle.[3]

Crackles detection has been also debated in many studies.

one method that was suggested is to split the detection process into three major stages:[4]

- a noise reduction filter is applied in order to delete the residual stationary noise in a nonstationary signal.
- a search of the waveform corresponding to a crackle.
- detected crackles are classified into two categories: fine and coarse crackles.

concerning the second step, a technique was offered for its implementation and is based on two steps: [5]

- A threshold (T) value is applied to the first derivative absolute value (FDAV) of lung sound to locate the "zone of interest".
- In this zone, a crackle is detected if certain conditions are verified.

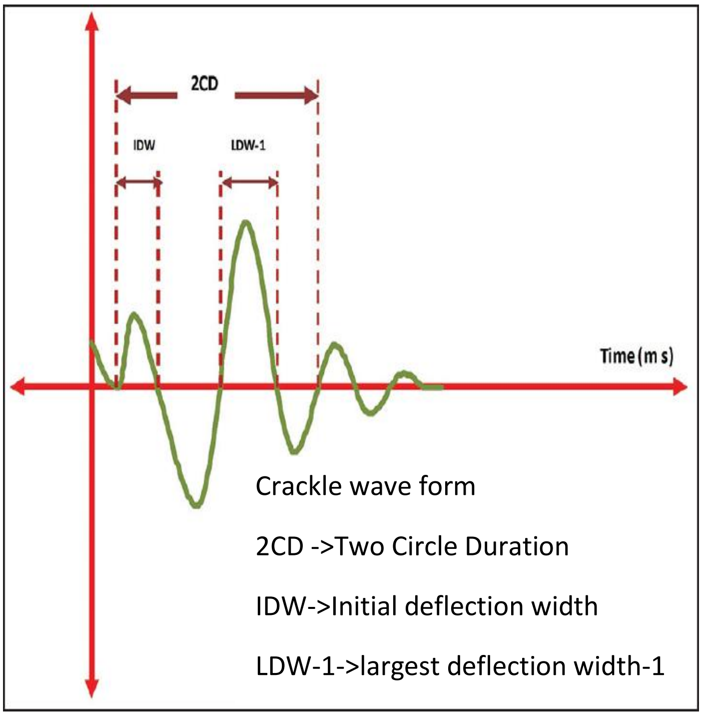


Figure 3: Crackle Waveform

[2] https://patents.google.com/patent/US5218969A/en
[3] https://patents.google.com/patent/US5218969A/en

[4] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2990233/
[5] https://www.ncbi.nlm.nih.gov/pubmed/9754686 (*)

Since technology companies usually aim to automatize our daily lives for facilitating them and for sure for their own profits, many companies had taken the responsibility to make progress in the whole crackles detection process.

So, the electronic stethoscope was suggested in the markets in many technology companies but as we mentioned before the final detection was not part of this service, final plots and recordings of the received signals were given by this stethoscope.[6]

Solution:

As previously mentioned, the detection and localizing the crackle sound are a pre-process that should be done.

Today this process is conducted by a regular stethoscope.

Clearly, using the stethoscope is not accurate enough, besides the time that it takes, especially in comparison with the short therapy time, which lasts 30 minutes.

Thus, conducting the pre-therapy diagnosis with a stethoscope is not recommended.

Two possible approaches will help us to achieve our goal for optimizing pre-diagnosing therapy:

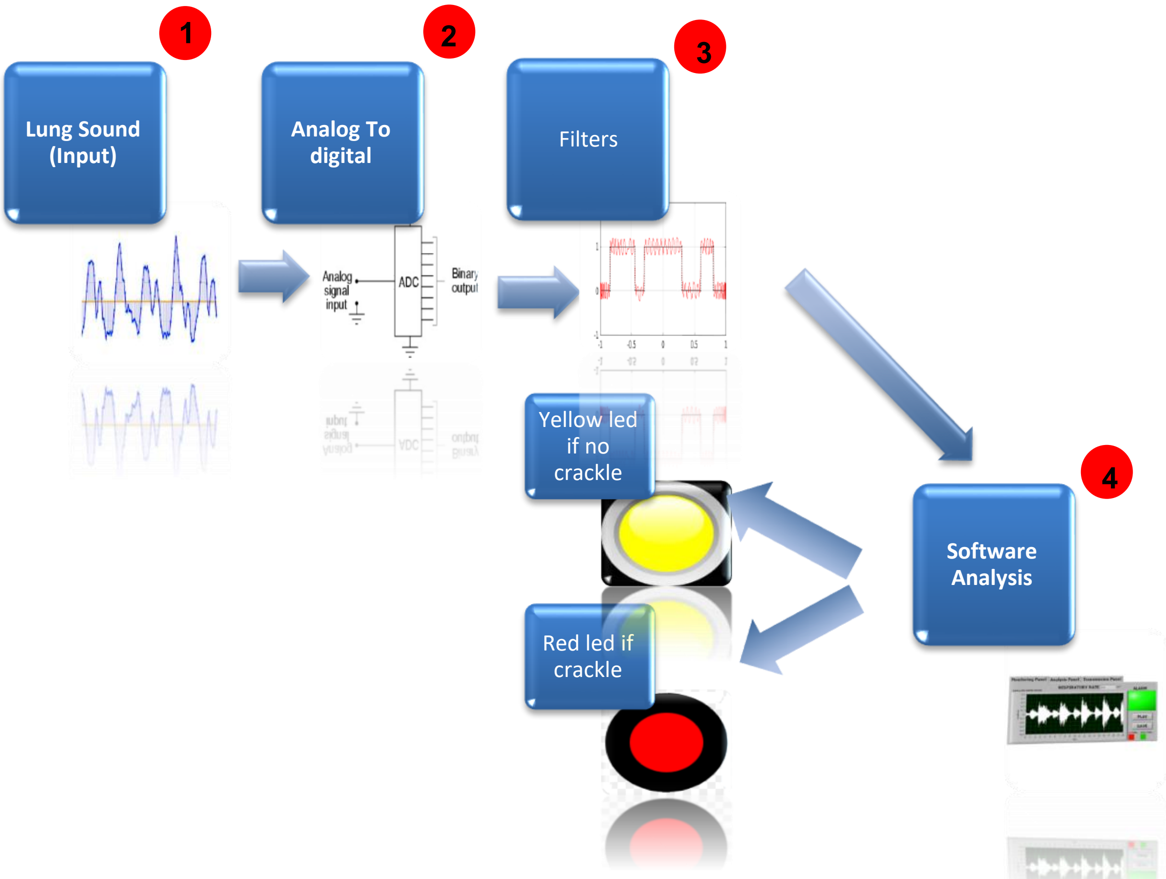
- machine learning- we can get audio recordings of CF patients breaths as a data set and start searching shared features to help us in the crackle detection process.
- Classical Signal Processing- we can do more research for conditions that should be verified to detect a crackle waveform in a received signal.

Proposed Solution:

since we are more experienced in signal processing and it might help us reach our goals earlier comparing to the second approach that demands more efforts to get enough data and so more time, we will choose it as an initial approach, unless it will not work as planned we will move to the machine learning.

[6] https://www.thinklabs.com/one-digital-stethoscope

Key Components:



1. Lung sound(input): lung sound (input): it will be recorded using the microphone as a first step, then a USB card.
2. Analog to Digital using ADC (Analog to Digital Converter).
3. Filters: will be applied by an audio editor
4. software analysis: using Matlab / Python

Solution Feasibility:

As mentioned before, the suggested solution will be attached to many tools aiming to make it accomplished.
Starting from recording the breath signal by using an appropriate microphone that could fit with the frequencies of the input.
Then a USB card for storing the received data.

An electronic stethoscope [7]can replace these two components.
Before start analyzing the signal, we should convert it from analog to digital using the ADC[8].
The audio editor that will be chosen is the WavePad[9].
The software analysis will be done by using Python as a priority, many libraries there

[7]https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4496820/
[8] https://www.elprocus.com/analog-to-digital-adc-converter/
[9] https://www.nch.com.au/wavepad/index.html

will help us analyze the received input, such as Scipy.signal[10].

Our challenge will be recording the received signal and filter it to fit our requirements (without the surrounded noises).

Material that has been read:

- The DSP course's material.
- Using microphone and REAPER software to receive the sound of the breath, page 4 · https://www.diva-portal.org/smash/get/diva2:1128908/FULLTEXT01.pdf
- Explanation of the reception process with the help of Raspberry Pi and the microphone · https://scribles.net/voice-recording-on-raspberry-pi/
- Technique helping in the identification process · https://www.ncbi.nlm.nih.gov/pubmed/9754686
- Electronic stethoscope https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4496820/
- Explanation, with audio, about the different sounds emitted by CF patients · https://hawaiicopd.org/media/lung-sounds/
- Explanation about the reception of the sound of the breath · https://cdnlearn.adafruit.com/downloads/pdf/usb-audio-cards-with-a-raspberry-pi.pdf

Technical aids :

- Hardware equipment:
  - Raspberry Pi
  - USB sound card
  - Microcontroller
  - Electronic stethoscope
- Software

  Learning how to use WavePad in order to filter our signal and any other audio modifications

  Libraries for signal processing (Python libraries).

[10] https://docs.scipy.org/doc/scipy/reference/signal.html

Semester Schedule:

September 2019	Getting the received signal and recording it
October 2019 - November 2020	Research for the adequate algorithm for the identification of the Crackle.
December 2020 - January 2020	Primary product will be displayed
February 2020 - April 2020	starting to apply the product on CF patients and comparing our results with physicians diagnosis
April 2020 – June 2020	Modifications will be done as needed