# Multichannel Recording and Classifying of Respiratory Sounds

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## Introduction

The Auscultation of the lungs with a stethoscope is an important and simple diagnostic method. It provides direct information about the structure (and function) of lung tissue that cannot be gathered by any other simple and non-invasive method. Changes in the quality of lung sounds are often directly correlated to pathological changes in the lungs. Particularly in practical medicine, auscultation is very important and considered a standard method of diagnosing and monitoring pulmonary diseases alongside lung function testing and chest x-rays. The multiplicity of lung sounds that can be observed makes it difficult even for a physician to arrive at a definite diagnosis. Today auscultation sounds are divided into two main groups: respiratory sounds and rales. Both respiratory sounds and rales contain important diagnostic information. Respiratory sounds include vesicular breathing, trachea air-flow sounds, and bronchial breathing. Rales include moist and dry rales, crackling, crepitation, rhonchus, and wheezing. The small selection of lung sounds mentioned above gives an idea of the difficulty of making a clear diagnosis.

A recent research project run jointly by Joanneum Research Graz and the Pulmonary Day Care Center at the LKH-Graz-West hospital in Graz, Austria intended to develop a system similar to a medical expert system to help the general practitioner or specialist diagnose lung diseases quickly and clearly. The objective of the first steps of the research project is to lay the foundation for the system by developing new sensors and the recording software as well as to do extensive physicals.

## Systems Analysis

In the first stage of the project the topics auscultation and interpretation of respiratory sounds were elaborated and prepared in the course of a systems analysis in order to allow for the optimal design and implementation of the recording system as well as a careful execution of the tests. Because of the various factors of influence on the lung sounds to be recorded and uncertainties concerning the interpretation of the sounds a standardized sequence of actions for the tests was established to obtain reproducible and objective auscultation results. The problem of not exactly reconstructable auscultation points on the thorax was faced by defining determinate positions for the sensors with respect to differences in build, position of the diaphragm and practicable location of anatomic reference points. For the purpose of achieving reproducible auscultation results the recording system should interact with a spirometer. Therefore one finding of the systems analysis were instructions for standardizing and controlling the respiration during auscultation by means of a spirometer.

Beside the factors of importance for the design of the tests, the person- and test-specific parameters and additional information which were finally fed in the recording software were derived from the systems analysis as well. Among these parameters were age, gender and body mass index of the person as well as information regarding sitting posture, disturbance of the sensors caused by rubbing-noises on the skin or a bad fixation of the sensors.

## The Recording System

The recording system for auscultation sounds was designed in two stages:

- Designing the sensors for picking up the lung sounds.
- Designing and implementing software for multichannel recording of auscultation sounds.

### The Sensors

Since sensors for picking up lung sounds are currently used by research institutes only, no sensors were available commercially. Therefore, new sensors were developed using miniature microphones. A search of the medical literature showed that previously most researchers had used air-coupled pickups. These consist of a miniature microphone fixed inside a tube in such a way as to create a cavity between the microphone diaphragm surface and the skin. The cavity is needed for converting the vibration signals radiated by the chest wall into air-borne sound. The shape of the cavity, however, heavily affects the quality of the recorded signal. In audio terms, the cavity represents a lowpass filter and makes the resulting signal sound "bass-heavy" to the physician. Various miniature microphones were tested for their suitability for picking up lung sounds. The "winner" was the miniature microphone CK 97-O from AKG Acoustics GmbH, Vienna. The first tests were performed with these sensors and assessed by Prim. Dr. Wurzinger, head of the Pulmonary Day Care Center at LKH-Graz-West hospital.

These initial tests using the newly designed sensors showed that these sensors greatly improved the transfer characteristic between the chest wall and the microphone so higher-frequency signals could be recorded as well.

**Figure 1:** Newly developed sensors for picking up respiratory sounds; miniature microphones are integrated in

the stethoscope head

## The Recording Software

Another important task besides the development of sensors was the recording of the lung sounds and the management of patient's data. Joanneum Research developed dedicated software for this purpose. The software does not only allow auscultation sounds to be recorded but also stores complete sets of patient data. The software provides a tree-type structure for handling patient data. A so-called patient data sheet is filled out for each patient. Data fields include physiological parameters, smoking habits, and any peculiarities of the patient's physique. A specifically implemented mask allows data about sensor positions, coughs during the examination, shilling of sensors, ambient noise, etc. to be retrieved. In the recording module of the software in a first step the optimal gain for each channel is automatically calculated to reach optimal audio quality. It is also possible to listen to each recording channel before the actual tests in order to check the operation of each sensor. Figure (2) shows the graphic user interface of the recording module.

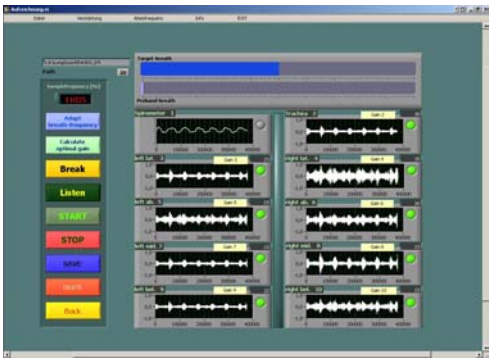

**Figure 2:** Graphic user interface of the module for recording respiratory sounds

# Physicals

The development of a diagnostic model that calculates a suggested diagnosis on the basis of the recorded lung sounds and additional factors requires a suitable database for creating a classification model. Two sets of examinations were needed for this purpose. One was a series of tests of healthy persons to quantify the influence of specific physiological features (age, gender, body mass index, etc.) on "normal" lung sounds and to find out whether they need to be considered within the classification model. The other was a series of tests of patients with three different lung diseases (chronic obstructive pulmonary disease (COPD), emphysema, fibrosis). In total 68 persons were examined: 44 healthy persons, 6 patients with COPD, 10 patients with emphysema, 7 patients with fibrosis, 1 patient with stenosis. Before the lung sounds were recorded, the persons were examined by a physician (lung specialist) who marked also the positions for mounting the sensors. Eight sensors were mounted on the thorax and one on the trachea (see Figure 3). In order to measure the air flow of breath, the persons had to breathe into a spirometer. The signal of this spirometer was synchronised to the lung sounds and was also recorded.

**Figure 3:** Eight sensors were mounted on the thorax and one on the trachea; the person had to breathe into an spirometer

During the recording of the respiratory sounds the quality of the signals was always checked by cyclic listening to the channels by a headphone. Figure 4 shows exemplarily the spectrograms of a healthy person (above) and a fibrosis-patient (below).

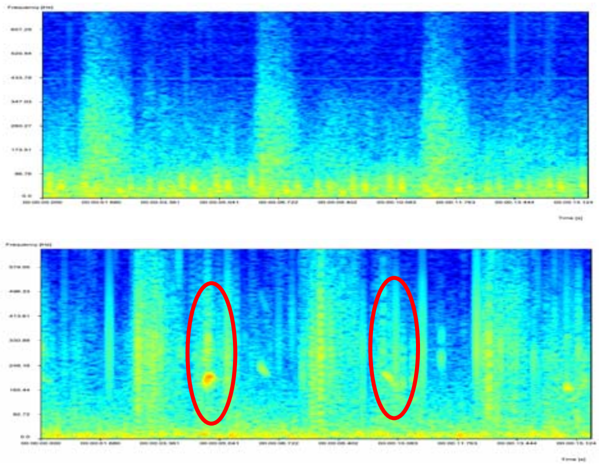

**Figure 2:** Spectrograms of respiratory sounds; healthy person (above), patient with fibrosis (below) – encircled areas are crackles

## Conclusions & Outlook

The results of the first analyses were highly promising and might be confirmed and optimized soon by further tests. For the enhancement of the models additional healthy elderly persons and some more patients should be examined. Furthermore a follow-up project is being planned to study the application of the system for monitoring therapy progress and controlling the course of a disease.

## References

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