Machine learning and multiparametric analysis of cardiorespiratory biosignals and environmental parameters

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***Abstract*— The analysis of the respiratory sounds is a valuable diagnostic tool for the detection and the follow-up of respiratory diseases such as Chronic Obstructive Pulmonary Disease (COPD). Adventitious sounds, such as wheezes, stridors, squawks and crackles, refer to additional respiratory sounds superimposed on breath sounds and are highly correlated to the respiratory function and therefore have a high potential to deploy pHealth solutions for COPD management. EIT is another biosignal that potentially can allow the continuous assessment of the ventilation function. In this talk we shall present the auscultation sound and EIT processing modules developed in the context of the EU Welcome (FP7-ICT-2013-10) project related to the integrated care of COPD patients.**

I. Introduction

Integrated care of patients with COPD and comorbidities requires the ability to regard patient status as a complex system. It can benefit from technologies that extract multi-parametric information and detect changes in status along different axes. This raises the need for generation of systems that can unobtrusively monitor, compute, and combine multi-organ information.

In the EU-funded project WELCOME (Wearable Sensing and Smart Cloud Computing for Integrated Care to COPD Patients with Comorbidities), such an approach is followed. Multiple types of data are recorded unobtrusively and medically relevant features are extracted to support decision making by the healthcare professionals. A core component of the Welcome solution is the sensor system, i.e. the sensors deployed on wearable technologies (vest) for recording and streaming bio-data to the mobile patient hub. This vest is equipped with sensors comprising synchronous and simultaneous acquisition of the lead ECG, chest sounds (heart and respiratory sounds), the photoplethismogram acquired at the chest as well as two parallel planes of EIT (electrical impedance tomography).

In this talk we will present the multi-parametric and integrated analysis module of the respiratory sounds and the EIT. Respiratory sounds are applied in order to assess adventitious sounds with clinical diagnostic and prognostic relevance for COPD patients, i.e., cough episodes, crackles and wheezes. EIT is currently applied for assessing the respiratory cycle phase and to identify COPD patients.

The first stage of chest sound processing is related to sound quality assessment. The approach explores heart sound auscultation in order to detect contamination by internal or external noise sources, i.e., it is based on the quasi-periodic nature of cardiac sounds. Noise contamination of chest sound will induce perturbation of the quasi-periodic property.

Cough episode counting is based on the detection of the explosive phase of cough sounds. These exhibit characteristic spectral and intensity features: cough sounds are inharmonic, exhibit clear concentration of energy in a limited set of frequencies and are of short duration compared to other, e.g., to speech. These characteristics are captured using inhamornicity, pitch, spectral flow and intensity features.

Crackles are short explosive respiratory sounds that are usually associated with the inflammation or infection of the small bronchi, bronchioles and alveoli. Crackles are non-musical and very often (coarse crackles) exhibit a very well defined “chirp-type” morphology. These characteristics can be captured using fractal dimension of the signal (it should be near 1), dispersion of the distribution and the Teager energy which is sensitive to frequency and amplitude of the signal. In this work we also use several musical features (e.g., MFCCs) as inputs to the classifier to capture the non-musical properties of the signal.

Wheezes are continuous whistling-type sounds induced by airways obstructions. The detection of wheezes is performed by exploring their musical and continuous nature using a set of musical features as well as the characteristic energy concentration in the time frequency spectrum. The later is assessed using an edge detection approach of the time-frequency domain.

In order to take advantage of the multiple sound sensors that are available in the Welcome vest, an information fusion approach is applied to the individual channel.

Pulmonary air flow is less than normal in certain lung areas of chronic obstructive pulmonary disease (COPD) patients. This leads to a higher ventilation inhomogeneity than in healthy subjects. Therefore, parameters that quantify the degree of this inhomogeneity provide useful information about the lung condition. Currently we are exploring several inhomogeneity indexes, such as the global and local inhomogeneity (GI) indexes of the electrical impedance tomography (EIT) in order to quantify the tidal volume distribution within the lung and to correlate them to the lung function.

In this talk experimental results using the described solution in several data collection studies involving both healthy and COPD volunteers will be provided and discussed.

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