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Deriving respiration from an unhealthy heart

This thesis deals with the extraction of respiration from the electrical activity of the heart, so called ECG-derived respiration (EDR). The main advantage of such approach is that only one medical device is used. Different methods have been tested on a dataset to verify the reliability of using EDR in patients with atrial fibrillation.

The breathing activity, the process to move air in and out of the lungs, is extracted in order to assess and monitor the health of a subject. However, the devices which are normally used to derive respiration are often bulky, expensive and uncomfortable. Another important issue is the risk of modifying the normal respiration, so giving unreliable results. In past years, many ideas have been proposed to obtain information about the respiration by considering its effects on another body activity, which can be more easily measured. An example is the heart electrical activity, which is worldwide recorded through sensors placed on the chest in a procedure called electrocardiography (ECG).

It is well known that respiration influences the ECG measurements in two ways: 1) the filling and the emptying of the lungs causes the displacement of the heart and affects the electrical measurements because of variations of the presence of air; 2) the timing of the heart beats is indirectly connected to respiration, so that the time interval between consecutive beats becomes shorter during inspiration and longer during expiration. The respiration obtained exploiting one or both of these effects is called ECG-derived respiration. Many methods have been proposed so far to derive EDR and a very few studies attempted to test their reliability in case of abnormal heart activity.

Therefore, this work aimed to verify the feasibility to derive the respiration of patients affected by atrial fibrillation from the ECG. Atrial fibrillation is a very common cardiac arrhythmia, regarding around 33.5 million of people in the world according to a study of 2010, and is associated with an increased risk of heart failure, ischemia, and stroke. The pathology is characterized by a rapid and irregular beating, initiated by a dysfunction of the upper chambers of the heart (the atria). Consequently, ECG signals in this condition cannot be used to extract respiration exploiting the timing of the heart beats, but using instead methods which only consider changes in beats appearance over time due to the cyclic filling and emptying of the lungs with air. Moreover, the fibrillatory activity of the atria affects the ECG signal in the form of small fluctuations, called f-waves, which may mask the breathing effects.

In this thesis, four EDR methods have been tested on a database containing simultaneous electrocardiographic and respiratory signals from 49 patients affected by atrial fibrillation. A code workflow has been designed to handle the characteristics of the recordings and reliably estimate the respiratory rate (number of breaths per sec) from the EDR signal and from the reference signal (Figure).
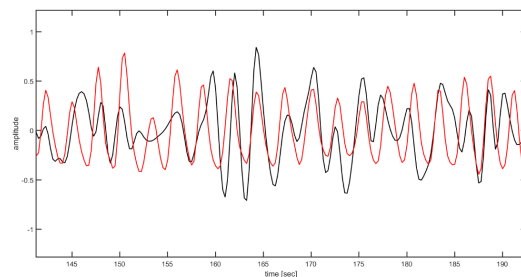
EDR signal (black line) and reference signal (red line)

The EDR methods have been implemented and adapted to the analysed dataset. Among them, the method proposed by Lazaro et al. in 2014 has demonstrated to estimate more accurately the respiration rate. The suppression of the fibrillatory activity has not proved to help the extraction of the EDR on the given dataset. However, further investigations on this and on how the positioning of the sensors on the chest surface and signal disturbances affect the quality of estimation are required. In general, all the tested methods achieved estimation errors higher with respect to previous studies on healthy subjects, but still comparable as order of magnitude. The results suggest that EDR is feasibile during atrial fibrillation, but further studies are needed to verify the results.