# Phase delay detecting methods to analyse the correlation between blood pressure and paced breathing

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The analysis of the temporal relationship between blood pressure and respiration is useful to understand the underlying physiological processes and in diagnostic applications. Our work is based on a clinical experiment, where ECG, blood pressure and capnograph signals were measured during paced breathing in normal and simulated hypovolemic states.

The *pulse pressure* defined as the difference of the blood pressures maximum (*systolic*) and minimum (*diastolic*) values in a cardiac cycle. The temporal fluctuations of these three quantities show correlation with respiration, furthermore the phase delay between these signals and respiration seems to be relevant in diagnostics. For this reason, the detection of this delay is important and useful, unfortunately in practical cases it can be difficult. Only a few heart beats occur during one respiratory cycle, therefore the sampling frequency of the mentioned signals is relative low, furthermore because of the heart rate fluctuations, the signals are unevenly sampled. Moreover, the inaccuracy of the respiration frequency and further physiological processes can distort the sinusoidal-like shape of the signals.

Several clinical and physiological studies used the fundamental methods of phase delay detection in time or frequency domain. Our addition to this problem is a comparison of these methods' efficiency in the case of differently distorted signals. In this work, we present a systematic analysis of the methods' reliability and accuracy on the measured time series and numerically simulated signals.

The heartbeats occur at different time instants in a respiratory cycle, therefore after synchronizing these cycles in a long-time registration using the square wave-like capnograph signal, we can calculate an averaged pulse pressure (or systolic/diastolic blood pressure) period between two inspirations/expirations [1, 2]. Then we can compute the time delay between the pulse pressure peaks/valleys and the falling/rising edges of the capnograph signal. Unfortunately the detection of these peaks can be rather difficult in most cases.

We have examined the usage of spectral-domain based detection methods also. These methods compute the phase delay using the relevant phase values from the signals' spectra or from the interpolated signals' cross spectra [3, 4].

The mentioned detecting methods have been applied on the data series measured in the clinical experiment. The spectral methods seemed to be more reliable at the cases where the peaks of the averaged pulse pressure cycle were hardly detectable. Furthermore, the accuracy and reliability of the methods have been tested on numerically simulated signals with different distortion and variance of breathing frequency and heart rate.

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