Contactless cardiac monitoring uses MEMS accelerometers

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A relatively new healthcare application for MEMS (Micro Electro Mechanical System) accelerometers is that of measuring a patient’s heart rate. Called Ballistocardiology (BCG), a MEMS sensor is able to monitor the function of the heart through the recoil effect caused by the blood flowing into the aorta.

An Electrocardiogram (ECG) has been the traditional method of measuring the heart’s function through a set of electrode contacts attached to the body. In contrast the BCG approach is contactless and allows the measurement of even more information regarding the volume of every heart stroke. Since the major blood flow around the body is along its length a single axis MEMS sensor is suitable for BCG use.

BCG offers good perspectives for application in preventive medicine, e.g. in detection of physical or mental stress and sleep quality or in the early detection of pathological conditions or attacks. This non-intrusive approach is also less stressful for the patient many of whom may be anxious when being attended to by medical staff.

The mechanical BCG signal follows the electrical signal with a delay of 30…40 ms. The amplitudes of the waves, see Figure 1, are a measure of the heart's stroke volume and from the timing one can see the general functionality of the heart as well as the heart rate and its variability, the latter very well describing the recovery state or stress of the person measured.

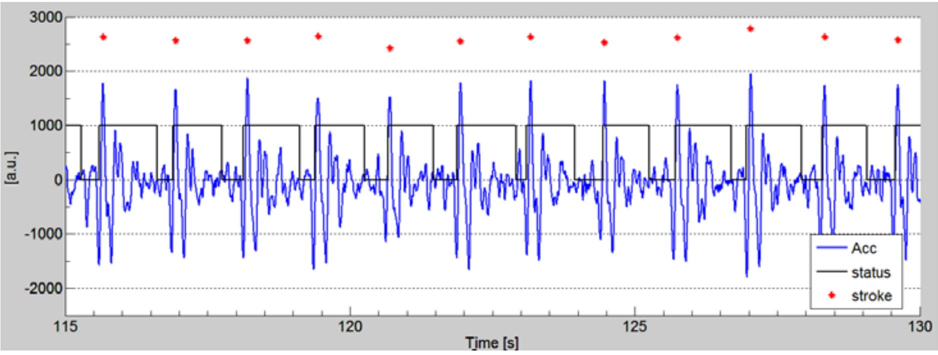

Figure 1: Measured heart beats and status

For example, Murata's MEMS-based BCG sensor technology uses very low noise accelerometer components with a noise density less than 20μg/√Hz, a level necessary for measuring the BCG signal. The technology also offers other important features for the reliability of the measurement, a controlled frequency response with mechanical damping and a 50,000 g shock resistance.

Advanced filtering algorithms in the embedded software (SW) in the module separate the BCG signal e.g. from the effects of the person moving, noise or bed resonances.

SW detects every beat (Figure 1: *). It reports the time for Heart Rate (HR) and Heart Rate Variability (HRV), the amplitude (Stroke Volume (SV)) for Stroke Volume Variability (SVV) and Respiration Rate (RR) as well as a status number based on the signal level.

The filtered status indicates bed occupancy, i.e. "0" means empty bed, "1" occupied bed and "2" person moving in the bed respectively. This parameter as such can be used for bed occupancy analysis or together with HRV, SVV and RR it is very useful for creating a Sleep Quality Index (SQI). When the person is moving in the bed, the BCG signal cannot be measured, but this is an important status for SQI. This status does not normally occur very frequently and as a consequence does not really affect overnight statistical analysis for e.g. sleep cycles or recovery.

The parameters reported by the BCG measurement can be filtered for overnight analysis (see Figure 2). For sleep cycle and recovery analysis most important parameters are HRV, HR and SVV, giving information on the sympathetic and parasympathetic nervous systems and the effects of respiration. Using HRV one can construct an index describing sleep cycles (Figure 2: HRV) and a filtered average of which being a measure of recovery (Figure 2: R Index). Other useful parameters for the indication of sleep state and recovery are HR (Figure 2: HR/10), relative respiration minute volume constructed from SVV and RR, Respiration Rate Variability (RRV) and the filtered status number (Sleep) indicating probable continuous periods of sleep.

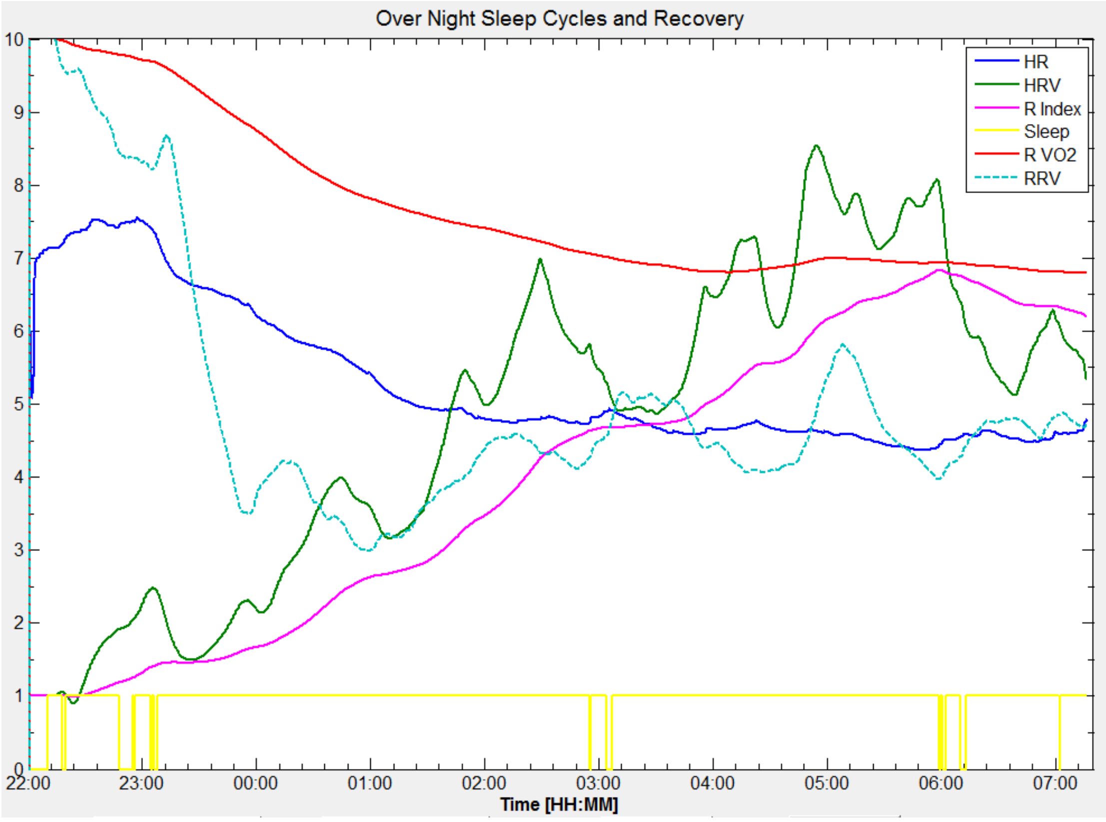

Figure 2: Overnight recording

The BCG measurement also gives the opportunity to have early indication on pathological conditions and potential near future sudden attack, in case they can be seen as an increased stress level in the autonomous nervous system. In addition overnight arrhythmia can be statistically analysed e.g. using a Lorentz plot, i.e. by plotting on the horizontal axis the n^{th} Beat-to-Beat (B2B) time and the following one $((n+1)^{th})$ on the vertical axis.

BCG is a totally non-intrusive cardiologic measurement with a large variety of application areas. These include e.g. home healthcare, elderly and infant care, sleep quality monitoring, athletes' recovery monitoring and hospital care.