Wrist Device for Automatic Sleep Staging and Quality Monitoring

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The study of sleep behavior becomes one of the most important fields of research in clinical science. Sleep is the main recovering time and bad quality of sleep is a prevalent factor accompanying chronic diseases such as sleep disordered breathing, diabetes, and cardiovascular dysfunction with enormous socio-economic impact. We developed a fully automatic sleep monitoring platform which includes the estimation of sleep quality indices as well as a sleep stage classification which will help diagnose these health risk factors. The resulting algorithm could be transferred into any wearable accelerometry and heart rate monitoring systems.

Modern lifestyles are irremediably associated with increased incidence of sleep disorders. More than 30 million people are accounted to suffer from chronic sleep apnea in the Western societies. The diagnosis and follow-up of sleep disorders require, still nowadays, the use of bulky and cumbersome monitoring devices. The standard way to monitor sleep structure is polysomnography (PSG), consisting in simultaneously recording brain activities, eye movements, and respiration. A long and accurate visual inspection by specialized personnel is required to establish a sleep profile commonly called hypnogram. There is a clear demand for new technologies that allow assessing vital signs during sleep without interfering with user comfort.

CSEM developed a watch-like device (see Figure 1) enabling to analyze the sleep quality. The device integrates a three-axial accelerometer, optical sensors, processing unit, communication capabilities, and power management. We demonstrated on a cohort of 26 subjects that the estimation of heartbeat intervals from photoplethysmograph (PPG) signals recorded with the device is in agreement with simultaneous beat-to-beat intervals (RR) as measured by an ECG at the thorax [1]. RR interval series are further analyzed in order to provide non-invasive information about the autonomic nervous system (ANS). The analysis of long-term recordings of four healthy subjects showed that heart rate variability (HRV) features computed from PPG-based RR intervals are in agreement with simultaneous HRV features computed from ECG-based RR intervals [2].

Figure 1: CSEM's wrist device embedding proprietary algorithms for automatic sleep staging and quality of sleep monitoring.

Spectral analysis of RR intervals in standard HRV frequency bands, as well as movement activity level were performed and used to differentiate three sleep stages: Wake (WAKE), rapid eye movement (REM), and non-rapid eye movement (NREM). The REM sleep—also called paradoxical sleep—is characterized by rapid and random movement of the eyes and dream activity. In healthy young adults, REM sleep normally occupies between 20% and 25% of the total night sleep duration. NREM sleep constitutes 70% to 80% of the total night sleep period and is characterized by low body metabolism and increased regularity in heart and breathing rates. Remaining 5% of the total night sleep duration is normally scored as wakefulness.

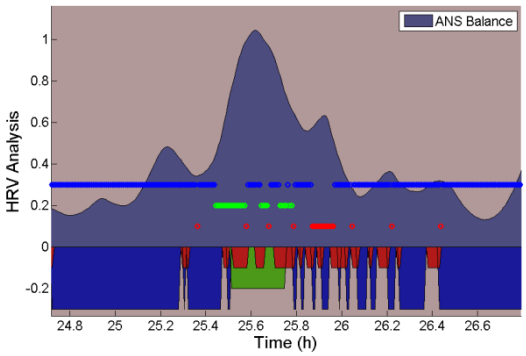

Figure 2: Extract from a sleep analysis using our algorithm showing the 3 Stages: WAKE (red), REM (green) and NREM (blue).

Fully automated sleep profiling were performed and showed promising results [3]. Figure 2 shows both the clinical annotated sleep stages (circles) and those extracted from our algorithm (filled areas) together with the ANS balance. Both REM and NREM stages computed from our HRV-based algorithm span wider than those using PSG [4]. Also, we can observe an overlap between the REM and WAKE states as these states can be mixed because they have very similar ANS features and micro-arousal are detected as well from the accelerometers.

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