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Stress Analysis in Drivers Using Wavelet Analysis

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Abstract:

The ability to acquire vital parameters and classify cognitive conditions opens doors to new technologies in diverse areas such as medical technology, automation, aerospace, fitness/wellness and security. For the statistical analysis of the measured ECG data, correlation coefficients and various hypothesis tests were used, which provide information about the correspondence between vital parameters and stress level. Furthermore, the theory of Krawchouk polynomials and the wavelet analysis based on it have been successfully applied.

Keywords: stress level, Baevsky's index, wavelet analysis, Krawchouk polynomials

Introduction

The monitoring and analysis of the stress level of people is used in many areas, such as space travel, autonomous driving and medical technology. Analysing the heart rate variability using an electrocardiogram ECG has proven useful for this purpose. The changes in the duration of cardiac cycles are measured, which guarantee the adaptability of the organism to external factors.

Since the beginning of space history, the widely accepted method to categorize the state of stress has been Baevsky's index. It is also used here to determine stress levels. Furthermore, the theory of Krawchouk polynomials and the wavelet analysis based on it are used.

Fig. 1. Driving Simulator

In the course of the new approach, ECG data sets were collected from a person in a driving simulator (Fig. 1), whereby the demands on the driver increased from test drive to test drive.

Motivation

The analysis of heart rate variability HRV starts at the beginning of space history. When Yuri Gagarin left earth, only breath and ECG were recorded as vital signs transmitted back to the ground control from the astronaut. To get a glimpse of his condition the ECG was examined.

Analysis of HRV during the first space flights have shown that during the launch of the rocket, which is the most stressful phase of the space flight, the HRV dropped significantly. Which means that the heartbeats occurred at equal intervals. In the following period, during orbital flight, the HRV increased again.

Roman Markovich Baevsky is a co-founder of space cardiology and was directly involved in planning and supervising the first human spaceflights in what was then the Soviet Union. The method described here is based on Baevsky's index SI. [1]

$$SI = \frac{AMo}{2\ Mo \times VR}$$

AMo (mode amplitude) is based on the number of RR intervals occurring at the mode. It is divided by the total number of RR intervals (see next chapter, Medical Background).

Mo (mode) denotes the most frequently occurring RR interval value of the measured series.

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VR (variation range) describes the range of variation of the measured RR intervals by calculating the difference between the largest and the smallest RR interval.

Medical Background

The heart rate variability describes the changing durations of heart cycles and is used to calculate the stress level. A cardiac cycle is the process from the beginning of one heartbeat to the beginning of the next. This period can be read from the pulse or from the electrical voltages that run through the heart, where the electrical voltages provide a more accurate measurement result.

The impulse for a heartbeat comes from the sinus node. It controls the frequency and intensity of heart beats. The sinus node is in the right atrium of the heart and is made up of muscle tissue and nerves. It sends electrical impulses to the rest of the heart and thus ensures that the muscle contracts and blood flows through the body. The strength of these impulses can be measured on the skin, resulting in an electrocardiogram.

To determine heart rate variability, the intervals between heartbeats are measured and their change is observed. Algorithms calculate these by using the time between two R-waves. This is called the RR interval.

Heart rate and HRV are controlled by the sympathetic and parasympathetic part of the nervous system. These two parts of the autonomic nervous system are predominantly antagonistic to each other. The sympathetic part is activated through external stimuli such as stress. It increases the heart rate by increasing the rate at which the sinus node releases electrical impulses. It also lowers HRV. The parasympathetic part of the nervous system is activated during internal processes such as the working of organs, but also through active exercise in the fresh air and progressive muscle relaxation. It lowers heart rate and increases HRV.

Wavelet Analysis

Similar to spectral analysis, wavelet analysis involves the expansion of functions in terms of a set of base functions.

In this approach, the Krawtchouk functions are used as the set of base functions for the wavelet analysis for the following reasons:

In contrast to Fourier analysis, wavelets are used to expand signals instead of trigonometric functions. They are based on a mother wavelet and are localized in time and space [2].

Krawtchouk functions as wavelets are suitable for denoising signals [3]. Noise is at most a hindrance to analysis of signals.

Krawtchouk polynomials are discrete orthogonal polynomials associated with the binomial distribution. They were introduced by Mikhail Krawtchouk in 1929 [4].

Results

With the help of common methods using correlation coefficients and hypothesis tests, the various indices of a data set, collected with the driving simulator have been examined for correspondence.

Furthermore, the various test drives have been checked for interrelationships.

The different frequencies of the mother wavelet have different degrees of goodness of fit with the signals. The linear connection of these with the SI has successfully been proven.

The highest values of the correlation coefficient between the wavelet analysis and indices are found at the lower frequencies of the Krawtchouk function. VR_D1-1 shows the highest linear correlation to the stress index.

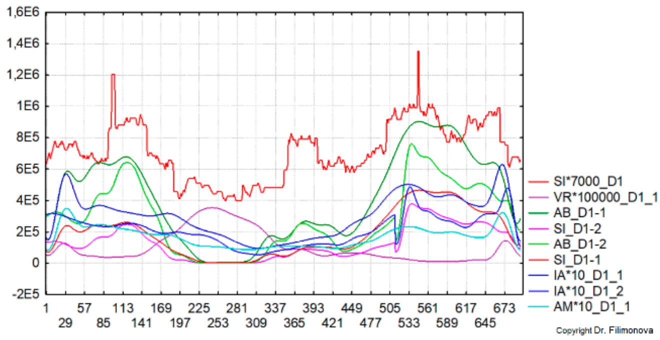

Fig. 2. Stress Level (red) against the wavelets

When looking at the frequencies of the wavelet analysis, we observed that some of them may produce a better model of the stress state than the original stress curve, which is why we are pursuing this approach in a follow-up project.

To do this, we want to collect data as part of test drives in public road traffic.

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