Features of signal absorption fronts of laser radiation in rapid diagnosis of human health

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The relevance of the work:

Due to environmental degradation, increasing stress and the emergence of new and dangerous diseases (e.g. COVID-19), in most cases people need to monitor their health regularly. To meet this challenge, various rapid real-time diagnostic methods have been developed. One of the most important reasons for their popularity amongst people is the ability to perform such diagnostics independently at the right time in different situations. Therefore, pulse oximetry has become very popular among the general public as a rapid diagnostic method.

Using pulse wave data, the presence and consequences of a number of diseases can be inferred and assessed. There are also a number of problems with modern pulse oximeter design which are related to measurement artefacts and the use of simple techniques in signal processing. This leads in some cases to very large measurement errors (more than 50%) and unreliable data interpretation. Therefore, the development of new techniques and various technical solutions to improve the reliability of the results of rapid diagnosis of human health is an extremely urgent task.

Materials and methods:

A mathematical model in the form of exponential dependencies for the treatment of pulse wave fronts by peak peaks, which was used previously, is not relevant in this situation. Therefore, we developed a new three-part methodology. Separately investigate the rise front, the fall front, and the pulse wave peak, taking into account the nature of changes in the adjacent steps. Therefore, we have developed three functions.

F(t) function for pulse wave crest studies:

$$F(t_n) = F\left(\sum_{n=m-p}^{n=m+p} \Delta\tau_n\right) = \left|\frac{A_n - A_{n-1}}{\Delta\tau_n}\right|$$

m is the number of the maximum step, p is a coefficient depending on the age of the person, A_n, $\Delta\tau_n$ are the amplitudes and durations of the steps.

Φ(t) function to study the pulse wave front:

$$\Phi(t_n) = \sum_{n=1}^{n=m-1}\left(A_n \cdot \sum_{n=1}^{n=m-1}\left[\frac{\Delta\tau_n}{\Delta\tau_m \frac{(m-1)}{p}}\right]^n\right)$$

Ψ(t) function to investigate pulse wave decay:

$$\Psi(t) = A_m \exp\left(-\frac{t}{\Delta\tau_k}\cdot\frac{n-m}{m}\right)\frac{n-m}{p(A_{k-1}-A_k)}$$

The values of t_n and t_k are subject to the following constraints $\tau_m < t$, $\tau_{k-1} <= t < \tau_k$, where k is the number of the decline step.

A feature of this model is that the relaxation process is considered for each step separately. The dependencies at the boundaries of the steps are then "stitched together".

Results:

Figures 1-3 show the results of a 22-year-old girl's pulse wave study using the developed formulas as an example.

Analysis of the data obtained shows their informative value. When comparing the spectral distributions (Fig. 1) of different people, significant differences in their structure, which are clearly associated with abnormalities in the human body, can be established. This makes it possible to establish the presence of pathologies or diseases.

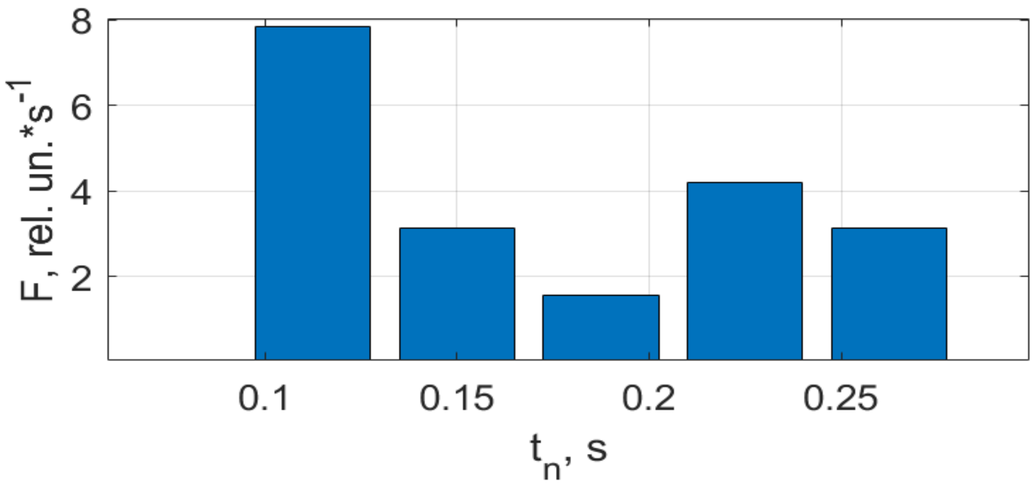

Figure 1. Spectral components of the pulse wave crest.

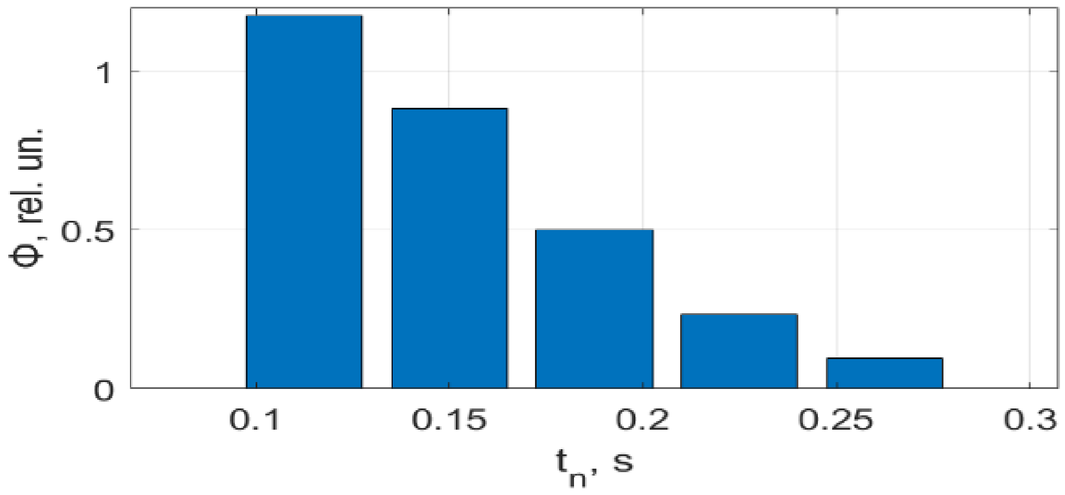

Figure 2. Spectral components of the pulse wave rise front.

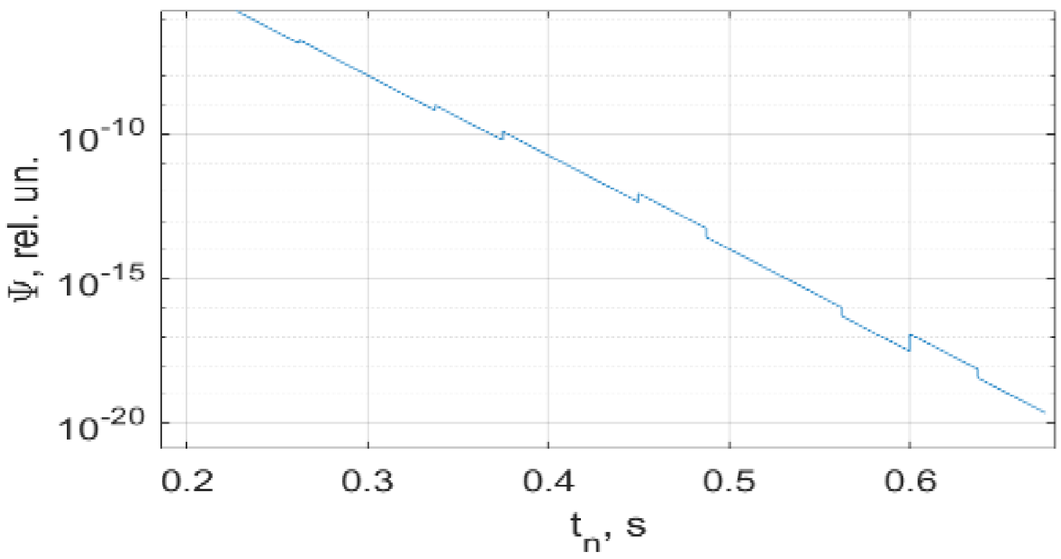

Figure 3. Spectral components of the falling edge of the pulse waveform.

Despite suffering from COVID-19 two weeks before the measurements, the results show a very good body condition (Figures 2 and 3).

Conclusion:

An analysis of the studies conducted has shown the effectiveness of the proposed technique for obtaining more information. However, the implementation of this technique requires a database that will make it more likely to identify disease at an early stage by the pattern of pulse wave changes.