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New Idea of Time and Life Science Data Registration

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***Abstract*—**The paper is destined for use in medicine, psychology, in man's self-development training; breathing technique's training, in the field of stress resistance, health promotion, strengthening of the capacity for work. We involve new technology for registration of time interval between two consecutive EKG RR intervals (R peaks) or pulse wave peaks, which consist of simultaneous registration of two time intervals: 1) the time between two consecutive R peaks, and 2) time interval from the beginning of registration and beginning of each wholesome R or pulsogram peak. Our new mathematical algorithm allows reconstructing all pulsogram or RR intervalogram, providing full use of time domain and also frequency domain methods.

***Keywords*—** Cubic spline, empty intervals, heart rate variability, RR interval, spline approximation, time interval.

I. Introduction

The paper is destined for use in medicine, psychology, in man's self-development training, breathing technique's training, in the field of stress resistance, health promotion, strengthening of the capacity for work; and it relates to the apparatus and methods for detection of the heart rate variability and it's may be used in providing biofeedback during training sessions of organism's vegetative balance and coherence [1] – [4]. The most prominent data analysis method – frequency time domain method needs very precise data acquisition technology, which is difficult to obtain, especially in practical everyday conditions, for example – in gym centers, individual biofeedback devices or apparatus for measurement of blood pressure and pulse. We involve new technology for registration of time interval between two consecutive EKG RR intervals or pulse wave peaks, which consist of simultaneous registration of two time intervals: 1) the time between RR intervals, and 2) time interval from the beginning of registration and beginning of each wholesome R or pulsogram peak. Our new mathematical algorithm allows reconstructing all pulsogram or RR intervalogram, providing full use of time domain methods.

Contrary to the view that under optimal conditions the heart beats sequence should remind the metronome, this is definitely not so [5]. Due to influence of Autonomic Nervous System, affecting the sinus node (nervous center, located in the heart, which activates each of the next cardiac cycle starting after a pause), pulse beats followed each other at different time intervals, and, as a result, the time span between two consecutive heart beats can vary over a wide range – from 400 to 1500 milliseconds. Plotting these following time intervals graphically, we get a wavy line. It is called the Heart Rate Variability (HRV) line. It turned out that this curve is very informative [5] – [12], [21].

When registering a heartbeat, we get a simple series of numbers (intervals between every two consecutive heartbeats in millisecond's, in average 70 numbers during minute, such as, for example, 721, 753, 835, 802, 799, etc.) from which we may derive many different indicators of the activity of vegetative nervous system, and, in addition, each of these numbers are characterized by strongly different physiological or psychological conditions. That is why we see a rapid increase of searches of new algorithms, approbation of new mathematical models.

Any technique that allows you to record an electrocardiogram is valid. As recording equipment does not play important role for the conditions (as it for many other so called psycho physiological methods, for example, galvanic skin response), the technical details of the HRV record is no longer even object for serious discussions in the scientific literature.

We should start with the fact that the HRV was one of the chief methods used for evaluation of physiological state in aerospace medicine and psychology (it was in the period around years 1950-1980, mainly in Russia [19], [20]). There are many studies that indicate the relationship between emotions and changed SRV indicators. HRV may be used as an indicator of risk prediction after myocardial infarction [5]. Until about 1980ties the only methods of, primary used in

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direct time regime were time domain methods, where some unpreciosity of data registration may be acceptable, somehow a great amount of very sophistical methods for registration process errors corrections were elaborated [7], [8] - [11], [21]. Nevertheless, it was useful practice to simply delete the wrong fragments of registered signals.

The situation changes when the frequency domain method for RR interval analysis enters. Due to sophistical mathematical algorithms used in frequency domain methods, also demands for data acquisition quality remarkably grows up. The fact is, that even the slightest registration error analysis results already vastly impressed, already vastly impressed, which could easily lead to complete distortion of the results of the analysis. Detection of atrial fibrillation in HRV signals needs analysis of irregular time series. Standard time domain and spectral method are not sufficient [5]. Detection of atrial fibrillation in HRV signals needs analysis of irregular time series. Standard time domain and spectral method are not sufficient [21]. In paper [22] authors have used modern discrete wavelet transform to find precise heart beat signal. But in this paper as in other mentioned us papers nothing was told and used lost heart beat disappears. In paper [5], as in the papers [6], [7] are used lost heart standard deviation in the form

$$\sigma_x = \sqrt{\sum_{n=1}^{N_1} \frac{\left(x_n - \overline{x}\right)^2}{N_1}}\ , \quad \sigma_x = \sqrt{\sum_{n=1}^{N} \frac{\left(x_n - \overline{x}\right)^2}{N}}\ .$$

Really the form is: where the number N is actual number of all heart beats, but N_1 is only fixed heart beats. This point is main idea of this our work: to reconstruction all real heart beats.

2. Our approach of data recording

Whereas the frequency time domain is the essence of each curve against the curve point of beginning, then we decided that it is better to go by road, which consists of 2 steps independently. First is registration. We traditionally registered one size of place (the time interval between the current and the previous heart beats) in addition to each pulse blow we register also time interval from the beginning to of the strike. And the second – we filled the pulse interval pulsogram registration empty space with the original mathematical algorithm assistance. Our new records show clearness fragment: 812,812,707,1520,693,2214,744,2960,748,3709,727,4436,716,5154,686,5841, etc.

If the fragment is without damage, then the time from the start (with fluctuations approximately 1 milliseconds (ms) range) corresponds to the sum of the length of the interval. It is also here in the demonstration the short numbers are together. If, however, we are significantly mistaken (or even extras stole movement, or any of the artifacts', this idyllic scene changes. We can see the following note fragment: 664,299859,833,300693,797,**301490,777,306827,700,309765,799,310564**,756,311321. To carry out analyses of this place. After 299859 (and 299.8 seconds) is the interval to 833 ms (0.8 sec), and it gives the correct next registered number: 300693 (300.6 sec). The same is true of the ensuing interval: sum up 797 ms (0.8 seconds), we get a number – 301490 (301.4 sec). Then comes the obvious recorded error. In this model 301490 with subsequent RR interval – 777 ms, we become obtain 302267 (approximately 302.3 seconds), but next notation is: 306827 (approximately 306.8 sec). This number is completely invalid for future use by the frequency domain methods. A number of our registration time, the 306827 allows us to solve the problem. But this is because it is this the real time since records began. Schedule this item takes its real location, and pulse curve are not distorted in any way.

The idea of time registration in living systems are not known to us. The work is published in another sector [23]. The time registration algorithm is applicable to modern high-accuracy target tracking system and designed on cubic spine interpolation.

3. Formulation of Problem and Nowadays Statement

Some ideas about mathematical aspects of the SRV methodology and measurements standards: the variations in heart rate may be evaluated by a number of methods. Perhaps the simplest to perform are the time domain measures. In these methods, either the heart rate at any point in time or the intervals between successive normal complexes are determined. In continuous ECG record, each QRS [5] complex is detected, and the so-called normal-to-normal (NN) intervals (that is, all intervals between adjacent QRS complexes resulting from sinus node depolarization's) or in the instantaneous heart rate is determined. The simplest variable to calculate is the standard deviation of the NN intervals (SDNN), that is, is square root of variance. Other commonly used statistical variables calculated from segments of the total monitoring period include SDANN [5], the standard deviation of the average NN intervals calculated over short periods, usually 5 minutes, which is an estimate of the changes in heart rate due to cycles longer than 5 minutes, and the SDNN index, the mean of the 5-minute standard deviations of NN intervals calculated over 24 hours, which measures the variability due to cycles shorter than 5 minutes.

The most commonly used measures derived from interval differences include RMSSD, the square root of the mean squared differences of successive NN intervals, NN50, the number of interval differences of successive NN intervals greater than 50 ms (milliseconds), and pNN 50, the proportion derived by dividing NN50 by the total number of NN intervals. All of these measurements of short-term variation estimate high-frequency variations in heart rate and thus are highly correlated. Since many of the measures correlate closely with others, the following four measures are recommended for time domain HRV assessment:

(1) SDNN (estimate of overall HRV),
(2) HRV triangular index (estimate of overall HRV),
(3) SDANN (estimate of long-term components HRV),

(4) RMSSD (estimate of short-term components HRV).

Shortly about Frequency Domain Methods. The analysis of the tachogram has been applied since the late 1960s. Power spectral density (PSD) analysis provides the basic information of how power (variance) distributes as a function of frequency. Independently of the method used, only an estimate of the true PSD of the signal can be obtained by proper mathematical algorithms.

Methods for the calculation of PSD may be generally classified as nonparametric and parametric. In most instances, both methods provide comparable results. The advantages of the nonparametric methods are:

(1) the simplicity of the algorithm used (fast Fourier transform(FFT) in most of the cases);

(2) the high processing speed.

While the advantages of parametric methods are:

(1) Smoother spectral components that can be distinguished independently from preselected frequency bands;

(2) Easy post processing of the spectrum with the an automatic calculation of low- and high-frequency power components with identification of the central frequency of each component;

(3) An accurate estimation of PSD even on a small number of samples on which the signal is supposed to maintain stationary.

The basic disadvantage of parametric methods is the need of verification of the suitability of the chosen model and of its complexity (that is, the order of the model).

4. Algorithm of Psychological Coherence and Vegetative Balance

Investigation is destined for use in medicine, psychology and psychophysiology, in man's self-development training, breathing technique's training, in the field of stress resistance, health promotion, strengthening of the capacity for work; and it relates to the apparatus and methods for detection of the heart rate variability and its use in providing biofeedback during training sessions of organism's vegetative balance and coherence [2]. According to offered method, the evolution of the heart rhythm's variability parameters is performed during the three time intervals between four consecutive heart beats [1], [2]; and, when the arithmetical difference between two consecutive intervals are identical (to previous set of intervals), a positive biofeedback signal (PBFS) is generated, but if the differences are with different sign, a negative biofeedback signal (NBFS) is generated; during time interval, greater than 20 sec, a "Central Index (CI)" is calculated, according to formula:

The sum of all PBFS*100/ (The sum of all PBFS/The sum of all NBFS) (in percent). PBFS, NBFS and CI are calculated in direct time regime, and are demonstrated on the screen of mobile training device or personal computer. They are used for ruling various systems (physical medicine apparatus, learning systems, different light-sound stimulation devices).

The invention relates to breathing technique training, stress resistance, health and capacity building areas, in particular, to apparatus and methodologies for determining heart rate variability and its application in biofeedback of various vegetative body's balance and consistency conditions during training.

It is well known that the autonomic nervous system (ANS) regulatory mechanisms are affecting many organs and systems of human body. The system works as a very complex physiological oscillator unit. One of the main functions of ANS is provision of the optimal balance between the oscillators. Any protracted regulatory balance disorder may lead to functional disturbances that can damage the human body. One of the main creators of this imbalance is emotional stress. There are many methodologies that apply for funds to reduce emotional stress, its positive impact on ANS regulatory function. This technology is designed to switch the ANS to specific "resonant" state, characterized by many physiological parameters synchronous oscillator, coherent, sine wave-like characteristic, such as heart rate (SD), BP (blood pressure), respiration rate (ER), and so on.

Good representing of resonant states is HRV or respiratory sinus arrhythmia where the heart rhythm (HR) oscillates synchronously with the respiratory cycle. Such synchronization automatically regulates many other body functions, including certain brain functions, including certain brain rhythms and metabolic processes. It is also known that the HRV is the representation not only of his rhythm, but also of the size of the state of harmony of many other autonomic nervous system reactions, so that could be used as the body's overall coherence and the coincidence index. Since the aim of the stress-reduction techniques is to create a resonance between the oscillating physiological parameters, it is important to be able to assess the dynamics of this resonance significance and stability in quantitative values, and generate feedback to reinforce positive changes.

To make SRV analysis and evaluation of the SRA parameters electrocardiographic (ECG), signal is commonly used. Inter-beat intervals are derived from the ECG as the intervals between two adjacent R-waves. It is very accurate and promising method, although quite inconvenient and relatively expensive. Photo-plethysmography is used as an alternative method, applying the small finger position sensor [5], [6]. The sensor emits infrared light into the skin. The emitted light in part, linked by blood flow. Light absorption/reflection coefficient is proportional to blood flow changes. Pletizmogramas signal contains periodic rapid elevations showing vascular pulsations. They can be used to determine heart inter-beat intervals, characterized by the distances between two pletizmogramas peaks. In all information sources that we know the source of information where the feedback is used for realization of HRV, the calculation algorithm is characterized by any of the similar characteristics – the time interval, necessary for heart rate records to allow quality and standards of appropriate HRV calculations. In classical case, by international agreement, this amount of time should be 5 minutes long [5]. After the prototype and analogues, the most modest number of pulse beats for, calculating the approximate SRV data must be at least100 pulse beats (1950-up to 80-year Soviet scientific data, which occurred in the Soviet cosmonaut psycho physiological monitoring of the condition) [19], [20]. Absolutely the smallest number of pulse beats needed to make something quite inaccurate, but calculate the average heart rate, pulse rate is 10-15 beats, but the average pulse is not the pulse rate variability.

This means that when working on a prototype or analogue techniques:

a) To collect data before the feedback signal for generation we must wait at least 1-6 minutes;

b) Each subsequent result can be obtained again only after 1-6 minutes;

c) The work in “moving average” mode is in better shape, because the waiting for “dead” period is necessary only in the beginning, and then we are able to be calculate for each pulse all SRV figures for the previous 1.5-6 minute period, but the improvement is somewhat apparent (illusory), because in essence we do not obtain a HRV description of each concrete short time moment, but we have the result of previous period average.

All these methods are satisfactory, if we are interested in slow physiological responses, which are changing in tens of minutes and hours. But usually all the physiological and psychological processes that we want to adjust to the reverse link are not so long. Even breathing, is used to improve to adjust the pulse variability. Very rarely, in exercises (including yoga), a respiratory cycle lasts longer than one minute. So, with the prototype and its analogues, we only very conditionally can hope that we as a feedback signal we truly use peculiar HRV indicators. But any stress during minutes may generate enormous changes, and that is why adequate HRV record figures are essential. The first part is exactly the same for all pulse variability detecting methods. It is as follows. By means of any standard EKG or pulse beat recording device time intervals between each successive electrocardiogram QRS complex or pulse wave must be fixed with the an accuracy of at least 1 ms.

But the momentary heart cycle length (or instantaneous pulse) rates in practice are not used as pulse feedback indicators. They are very changeable, and physiological benefits lies precisely in its ability to characterize this variability mathematically, i.e., to find an algorithm that is the best and most practical to characterize a specific physiological conditional or situation, and can be used as feedback indicators. Standard HRV indicators are appropriate for scientific purposes, but are less adequate for scientific purpose as biofeedback elements. Our work allowed us to see the possibility to derive a special mathematical algorithm for processing the instantaneous pulse data with the aim to generate a realistic indication of the vegetative n. s. regulatory processes, and, thus, create a parameter, which could serve as a convenient indicator used for biofeedback.

Usually calculations that are offered and used for biofeedback signal need at least 100-500 test points, located before the instantaneous time point recorded. For realization of our algorithm only 2 points before the instantaneous time point records are necessary, and, more importantly, the conclusions we make with only one, the most recent time interval, with its relationship to the previous interval, which is just a report. The result therefore does not describe the average physiological state of several minutes, but only about 1 second. Thus, feedback can be shown immediately after the fourth heartbeat.

Our algorithm is implemented as follows.

The following convention is adopted:

P(n)=the time moment of the current heart beat (fourth, if the calculations carried out at the fourth heart percussion);

P(n-1)= third, if the calculations carried out at the fourth heart percussion;

P(n-2)= second, if the calculations carried out at the fourth heart percussion;

P(n-3)= first, if the calculations carried out at the fourth heart percussion;

T(n)=time interval between P(n) and P(n-1);

T(n-1)=time interval between P(n-1) and P(n-2);

T(n-2)=time interval between P(n-2) and P(n-3).

Beginning from 4-th pulse beat and forth, each pulse beat is granted with following designation.

(Parameter V(x)=+ or V(x)=-) according to following algorithm:

V(n)=”+”, if T(n)>T(n-1);

V(n)=”-”, if T(n)<T(n-1);

V(n)=”0”, if T(n)=T(n-1);

V(n-1)=”+”, if T(n-1)>T(n-2);

V(n-1)=”-”, if T(n-1)<T(n-2);

V(n-1)=”0”, if T(n-1)=T(n-2).

On each pulse beat beginning from the fourth beat, the following calculations are made:

If V(n)=”+” and V(n)=”+”, then PBFS (Positive Biofeedback Signal)=PBNS+1;

if V(n)=”-” and V(n)=”-”, then PBFS (Positive Biofeedback Signal))=PBNS+1;

if V(n)=”+” and V(n-1)=”-”, then NBFS (Negative Biofeedback Signal))=NBNS+1;

if V(n)=”0” and V(n-1)=”+”, then NBFS =NBNS+1;

if V(n)=”+” and V(n-1)=”0”, then NBFS =NBNS+1;

if V(n)=”0” and V(n-1)=”-”, then NBFS =NBNS+1;

if V(n)=”-” and V(n-1)=”0”, then NBFS =NBNS+1;

if V(n)=”0” and V(n-1)=”0”, then NBFS =NBNS+1.

For time period of 20 sec or longer the “Central Index (CI)” is calculated as following:

“Central Index (CI)”=amount of all PBFS/ (all PBFS and NPBS amount)*100 (percent).

This calculation can be performed in both ways: immediately after each heartbeat, or as a retrospective analysis of a particular situation, particular time interval may be made. Since CI is always within the range between 0 and 100%, and the value estimate is unchangeable, it may well be used as comparative indicator and benchmark for the one and the same person at different life, work and health situations, as well as various human condition inter-comparisons. CI is very dynamic, if you use it as a moving average, for example, from 20 heart beats, and, at the same time, it is also a solid, stable indicator, that can be used to compare averages for different people, or one and the same person figures on different days, months or years, if the expense of a 5-minute long recorded is performed in standardized conditions. Many of our measurements allow introducing approximate boundaries of these index-readings. Above 50% usually mean good health and high performance. Specially trained people, who manage yoga and deep breathing techniques, are able to increase this figure, and long to hold 70-90% range. To emotional stress, the figure falls below 30%, and some situations, it is only 3-6%.

5. The new deeper algorithm

Thus, as follows from the previous one, and making it simpler, from the RR intervals we evaluated and pointed out one characteristic - whether each of the following RR intervals maintains their direction, or the direction changes. Biological sense of such interpretation in our point of view is the following: the longer are the unchangeable direction periods, the better and more beneficial are the circumstances for vegetative nervous system and organism as the whole: better are the possibilities for stabilization and recovery for many processes in human body. Our previous algorithm demonstrates it dramatically – the rest position in comparison to anxiety, of psycho-emotional tension can be reduced 10 and more times.

However, as demonstrated in our future work, our algorithms proved necessary to be developed further, because it revealed new opportunities to analyze and understand more deeply the details of many aspects of the adaptation process, particularly emotional stress. We found that this one-way RR interval amount consists of individual accurately determined fragments. This means the following: RR intervals of the debt may be extended or reduced in continuous series – the two, three, four, and so on. Further, we found that this approach opens new opportunities and much broader understanding on the general regulation and the adaptation processes of human body. We found that mathematically the most obvious and most convenient way is to analyze this process of adaptation in the form of histogram. Therefor we created a new mathematical algorithm for investigation of heart rate variation.

It is as follows:

```
ab1ind=0;
ab1sk=0;
vidab1ind=0;
ab1etaps=0;
ab1enkurs=0;
ab1kopsk=0;
for (v=5; v<=z-5; v++) {ab1kopsk=    ab1kopsk+1;
ab1etaps=0;
if (rr[v]>rr[v-1] && rr[v-1]>rr[v-2]) {ab1ind=ab1ind+1;
ab1sk=ab1sk+1; ab1etaps=5;}
if (rr[v]<rr[v-1] && rr[v-1]<rr[v-2]) {ab1ind=ab1ind+1;
ab1sk=ab1sk+1; ab1etaps=5;}
if (ab1etaps==0){ hi1=hi1+1;
if (ab1ind==2){hi2=hi2+1;}
if (ab1ind==3){hi3=hi3+1;}
if (ab1ind==4){hi4=hi4+1;}
if (ab1ind==5){hi5=hi5+1;}
if (ab1ind==6){hi6=hi6+1;}
if (ab1ind==7){hi7=hi7+1;}
if (ab1ind==8){hi8=hi8+1;}
if (ab1ind==9){hi9=hi9+1;}
if (ab1ind==10){hi10=hi10+1;}
if (ab1ind==11){hi11=hi11+1;}
if (ab1ind==12){hi12=hi12+1;}
if (ab1ind==13){hi13=hi13+1;}
if (ab1ind==14){hi14=hi14+1;}
if (ab1ind==15){hi15=hi15+1;}
ab1ind=1;
}
}
vidab1ind=hi1+hi2+hi3+hi4+hi5+hi6+hi7+hi8+hi9+hi10+hi11
+hi12+hi13+hi14+hi15;
hi1=hi1*100/vidab1ind;
hi2=hi2*100/vidab1ind;
hi3=hi3*100/vidab1ind;
hi4=hi4*100/vidab1ind;
hi5=hi5*100/vidab1ind;
hi6=hi6*100/vidab1ind;
hi7=hi7*100/vidab1ind;
hi8=hi8*100/vidab1ind;
hi9=hi9*100/vidab1ind;
hi10=hi10*100/vidab1ind;
hi11=hi11*100/vidab1ind;
hi12=hi12*100/vidab1ind;
hi13=hi13*100/vidab1ind;
hi14=hi14*100/vidab1ind;
hi15=hi15*100/vidab1ind;
println(ab1kopsk);
println(vidab1ind);
```

This algorithm is the new mathematical model of the paper [3], [4]. This allows you to get a new view of the HRV, dividing the groups by one direction, so called specific determined fragments. Authors understand that this new view is important for medical usage, but the goal of this article is not a solely medical. The main task of this article is to make the new, in-depth mathematical algorithm. Authors plan to continue this new direction with other publications.

Further is the presentation seven images, in which the RR intervals in specially determined fragments appear in the form of a histogram. The following images describe the graphical representation of our algorithm. The four figures represent the spiritual practices of mentally developed individuals. The following three pictures show these people in process of meditation. The third person is also practicing spiritual singing and collection of the healing herbs, etc. Additionally about the role of music writes scientific press [14], [15]: “Each disease is one musical problem.” Papers [15] – [18] investigate the heart rate variability.

First seven figures give three human after our algorithm detailed schedules. The first, third and five figures show third humans on the restless stage. Next two, four, six and seven figure sows contemplating human. The seven figure sow contemplation human who sings. Figures 1. -7. show the figure given in this human’s spirit by the authors' methodology.

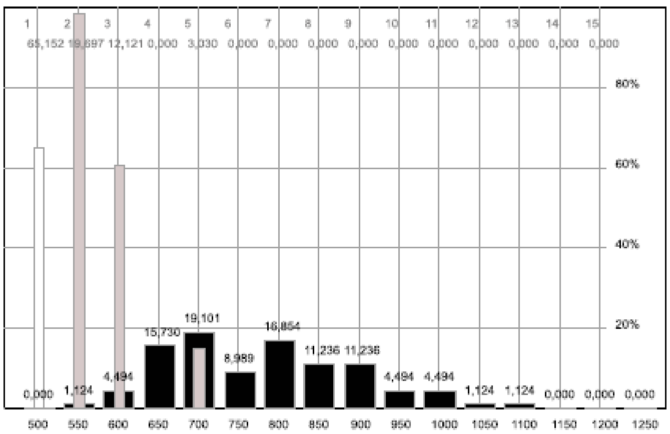

Fig. 1. Histogram for restless body for first human. Green and greyish is our algorithm from section 3; paper [1], patent [2]. Light color is deep algorithm [4]. Black is from books [19], [20].

The works of Russian authors in the 1960s and 1970s of previous century are related with the preparation of the spaceman for cosmic flights [19], [20]. Because this reason we added the results of these studies in figures 1-7. We can say that three human are case report and give some working hypothesis later.

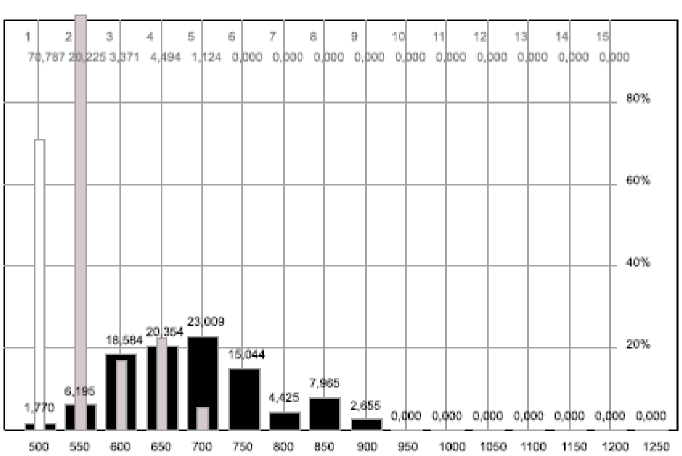

Fig.2. Histogram for contemplation body for the first human. The text coincides with the drawing figure 1.

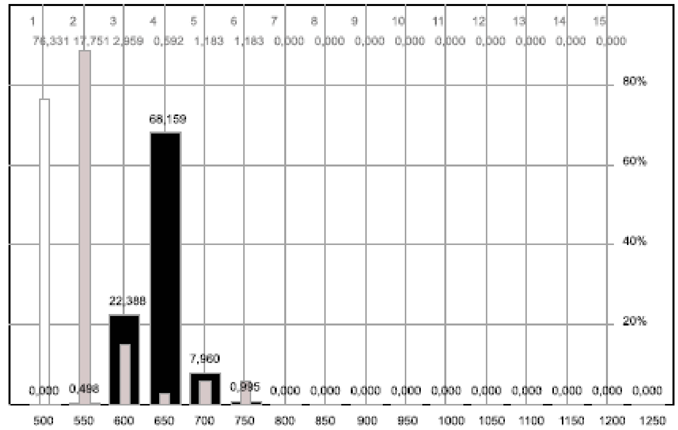

Fig.3. Histogram for restless body for the second human. The text coincides with the drawing figure 1.

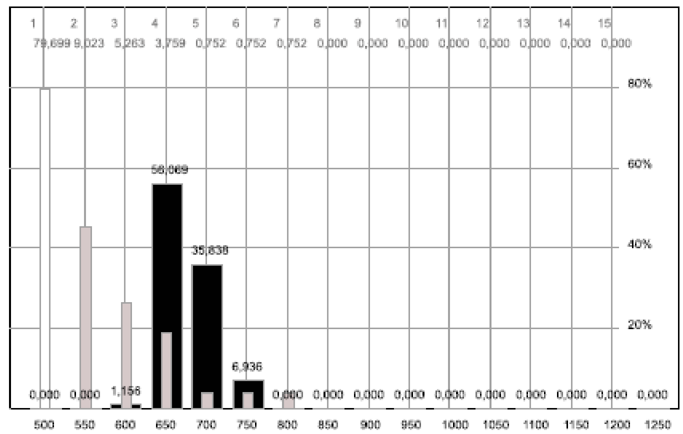

Fig.4. Histogram for contemplation body for the second human. The text coincides with the drawing figure 1.

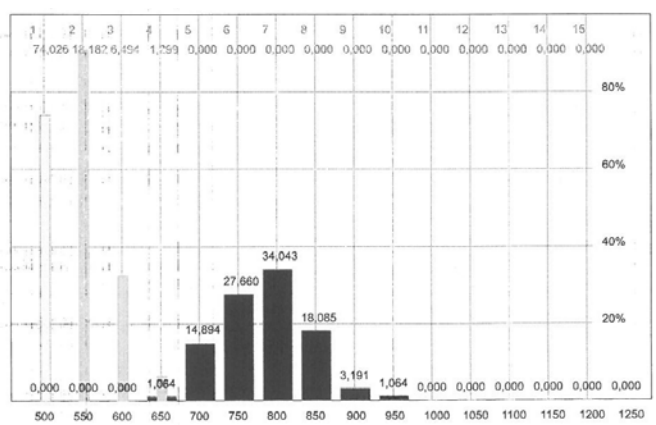

Fig.5. Histogram for restless body for the third human. The text coincides with the drawing figure 1.

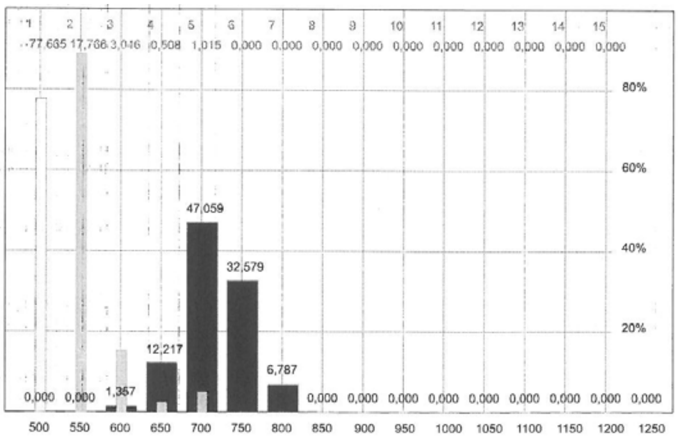

Fig.6. Histogram for contemplation body for the third human. The text coincides with the drawing figure 1.

After these figures we give explanation of content of the previous seven figures. A little further in figures in 8 - 13 we compare our in-depth mathematical algorithm with recent interesting Finnish Biosignal Analysis and Studies of Medical Imaging Group [9] – [11].

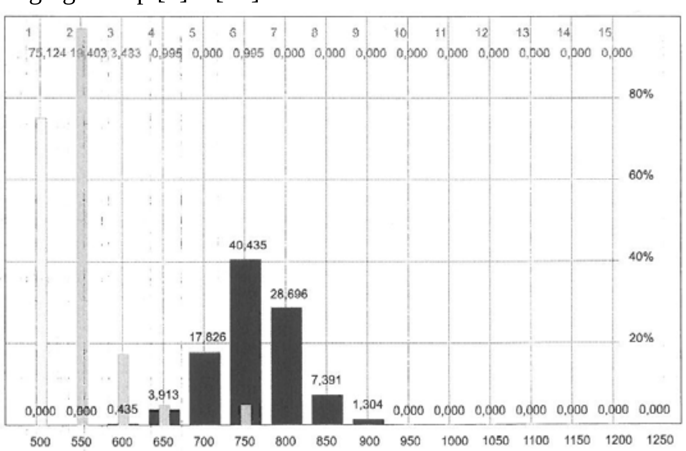

Fig.7. Histogram for contemplation on natural favorite views for the third human. The text coincides with the drawing figure 1.

However, as our next work showed, our algorithm had to be developed further, because we found out new possibilities to analyze more detailed and understand several details of process of adaptation, especially in circumstances of emotional stress. We found out that the sum of these one directional RR intervals consists of separate particularly determinable fragments. It means that RR intervals can shorter or be prolonged in continuous series – two by two, three by three, etc. With great skills, this number can reach 10 and more. Our small experience shows that on the apparatus on portable computers and other devices allow you to get more than the 8-10 one row values existing heart rate variation. Elimination of these devices, manages to get increased rhythm length to 12-13 beats.

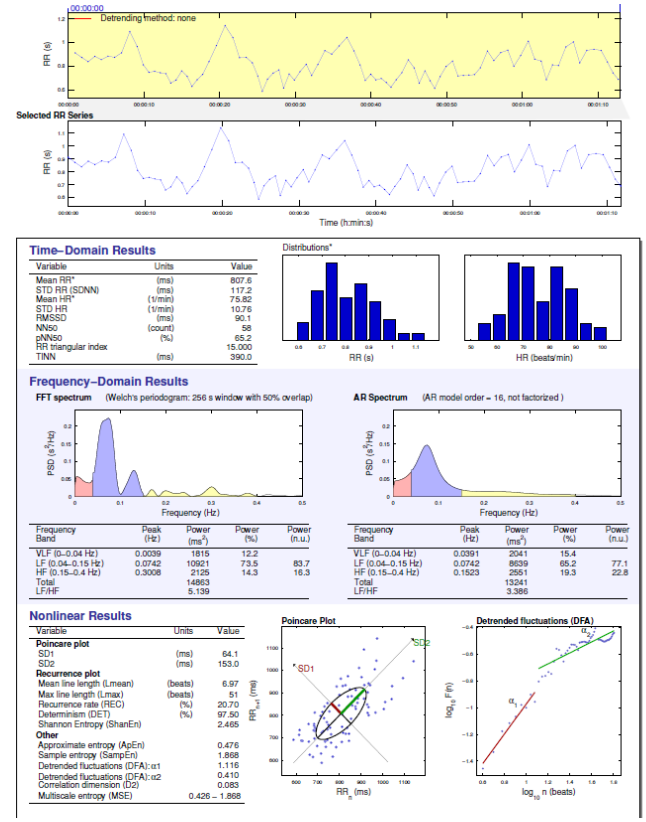

Fig. 8. Finnish figure from papers [9] – [11], comparable with our fig, 1.

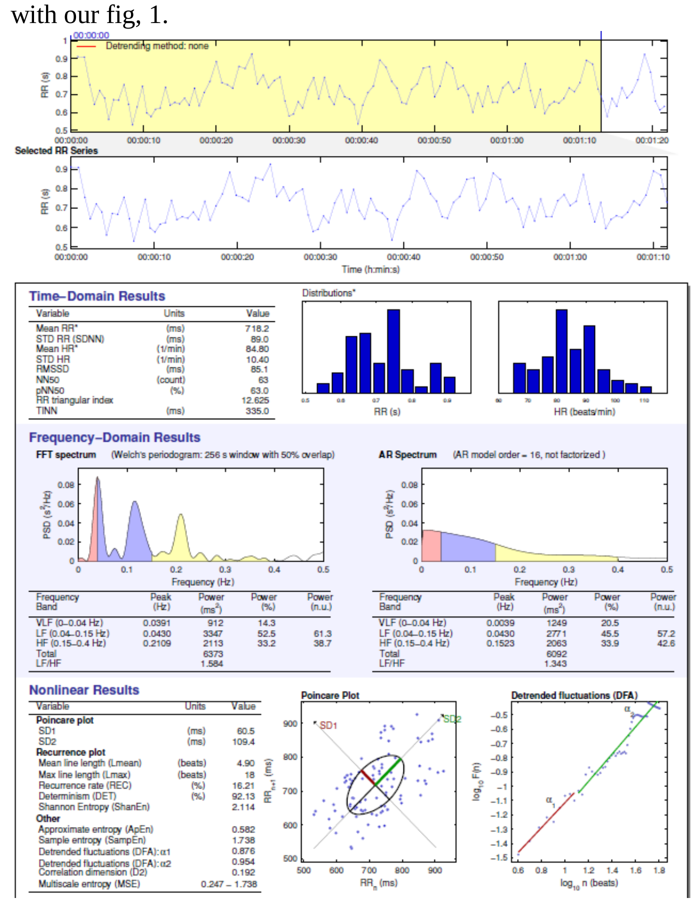

Fig. 9. Finnish figure from papers [9] – [11], comparable with our fig, 2.

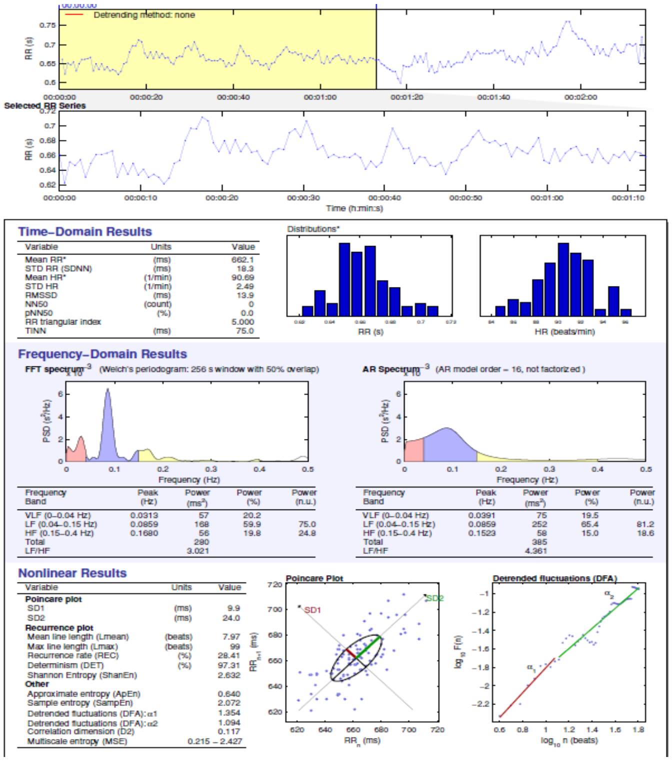

Fig. 10. Finnish figure from papers [9] – [11], comparable with our fig, 3.

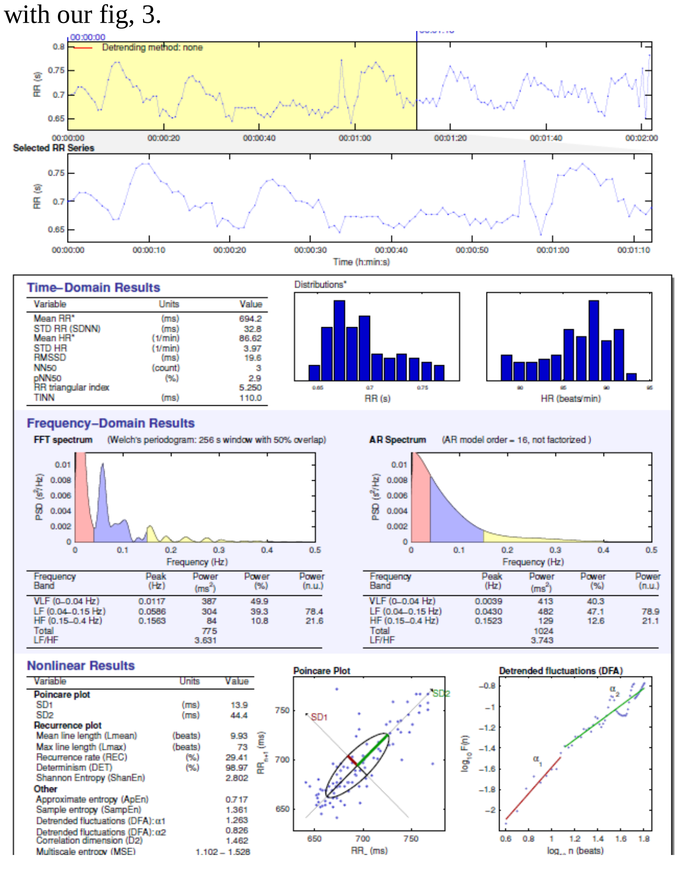

Fig. 11. Finnish figure from papers [9] – [11], comparable with our fig, 4.

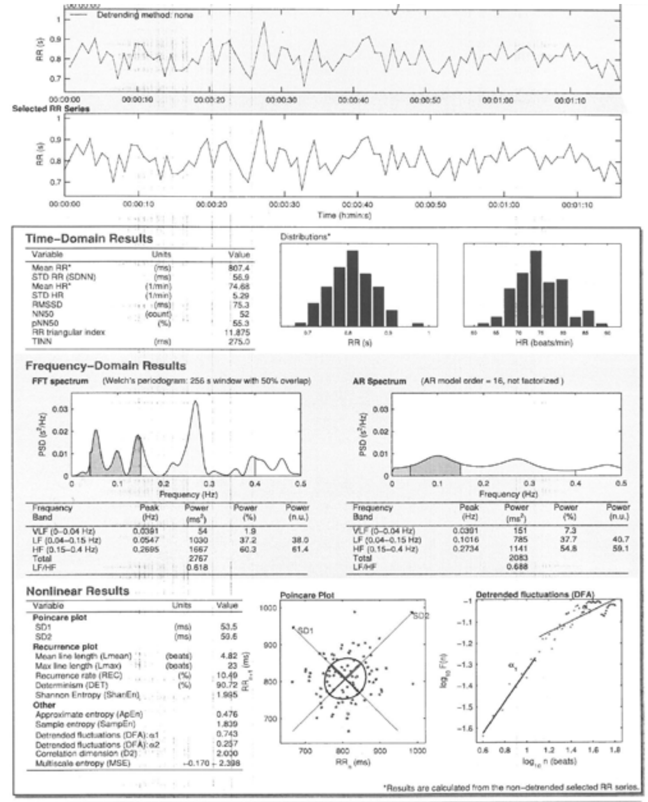

Fig. 12. Finnish figure from papers [9] – [11], comparable with our fig, 5

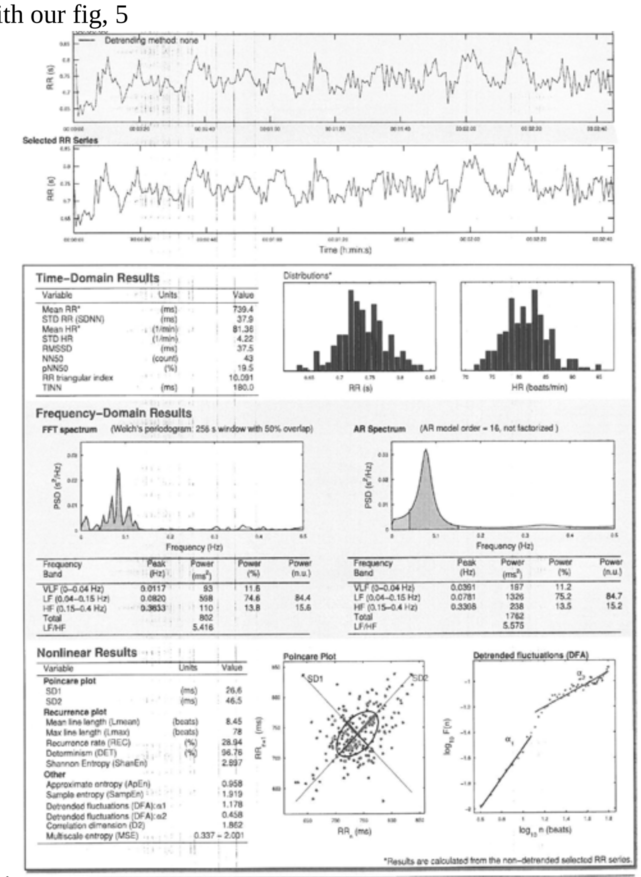

Fig. 13. Finnish figure from papers [9] – [11], comparable with our fig, 6.

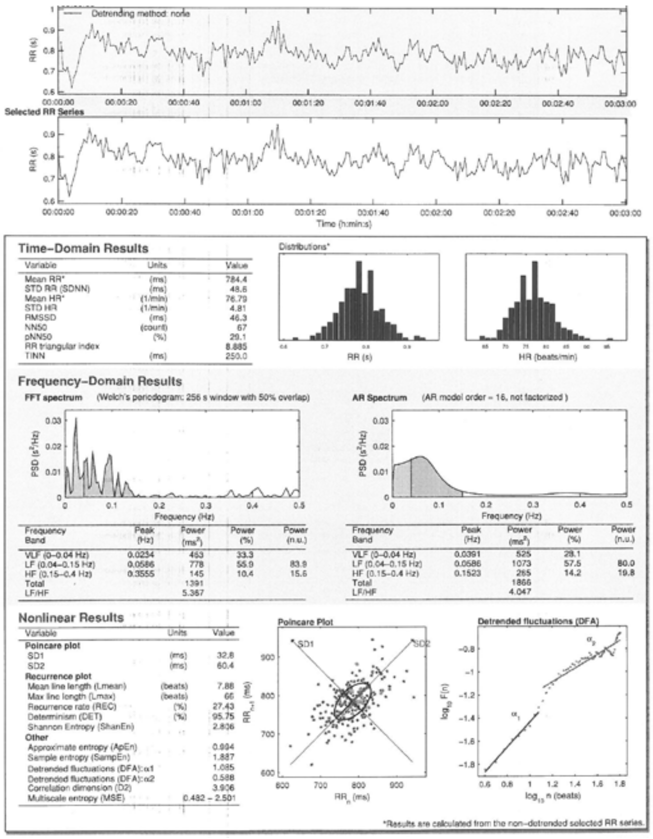

Fig. 14. Finnish figure from papers [9] – [11], comparable with our fig, 7.

Finnish scientists developed a complex, (which you can obtain from authors). This is a significant investigation, published in [9] - [11]. Recently appeared a new complex of programs, which was developed by Finnish group of scientists, an these programs can be obtained freely. We used this complex for data which are described in fig.1 - 7 by our algorithm. As we can see, our new algorithm and Kubios HRV 2.2 give different results. It will be interesting to compare them in future. Our new algorithm is on sub-sensorium level. We explain it as parameter N. (In all our schedules, annexed to the explanatory parameters). Around half of them are from previous century 70-ties studies with Russian cosmonauts. The rest is our established parameters.

Index. 1.-SDNN: standard deviation of the NN interval; 2.-RMSSD: square root of the mean squared differences of successive NN intervals; 3.-AA index: 4.-amplitude of mode; 5.-delta; 6.-pNN50; 7.-variability coefficient; 8.-VRR; 9.-Stress index; 10.-Vegetative Index.

First individual

Index	1.	2.	3.	4.	5.
Fig. 1	116.7	90.08	48.24 %	19.10 %	554.0
Fig. 2	87.51	85.55	40.37 %	23.01 %	395.0

6.	7.	8.	9.	10.
65.17%	14%	2.58	24.63	14.61
62.83%	12%	3.62	41.61	13.98

Second individual

Index	1.	2.	3.	4.	5.
Fig. 3	24.86	16.15	31.98 %	68.16 %	162.0
Fig. 4	31.14	23.43	34.32 %	56.07 %	141.0

6.	7.	8.	9.	10.
1.00%	3%	9.50	323.6	3.28
4.05%	4%	10.91	305.9	4.80

Third individual

Index	1.	2.	3.	4.	5.
Fig.5	56.70	75.27	32.22%	34.04%	323.0
Fig.6	37.80	37.52	27.19%	47.06%	209.0
Fig.7	48.44	46.29	31.86%	40.43%	324.0

6.	7.	8.	9.	10.
55.32 %	7%	3.87	65.87	12.13
18.55 %	5%	6.84	160.83	7.15
27.83 %	6%	4.12	83.20	8.74

Now we to return back to our figures 1-7 and use our parameters [3], [4]. We compare the pulse. Immediately we conclude practically that from restless body to mediation human body go to tension: first human 74.4 – 83.9, second human 90.0 – 85.8 and third human 74.2 – 81.1 – 76.5 heart rate. The rate of second individual's pulse calms down – goes to relaxation, but the pulses other two – go up; so it is interesting, this clearly shows that we can't presume meditation only as a state of relaxation. The pulse rate in the state of meditation will decrease for those, whose pulse were initially too high, but will go up for those whose was too low. The state of meditation requires slight pulse acceleration – as is the whole organism mobilization. And yet – we intuitively look for indicators that go in the same direction. And indeed we found, and so was directly ours criterions.

Now we speak about white color on figures 1-7. About the symbols of first drawing: on the bottom axis is displayed heart rate readings of length in milliseconds. The top axis shows how much is length changes. Our article [2] describes only one length. This drawing is marked with a white. In the article [3] given algorithm, which enables you to capture 2, 3, 4 and up to 15 changes in the same direction they go rhythm changes. Note that the numbers are given as percentages of all sizes conform to this size. Naturally, all size is a sum of one hundred per cent. As has already been said, the black bars are Russian spaceman criteria.

We can consequence that at histogram by value 500; our parameter $N = 1$. The column goes up: 65.1 -70.8; 76.3 – 79.7; 74.0 – 77.7 – 75.1. Second consequence is connected with two highest columns on the figures 1-7.

For the second human these numbers are 700, 750; our parameters $N = 5, N = 6$. Columns are above: 0.6 – 3.8; 1.2

– 0.8. For the third human these numbers are 650, 700,750; our parameters $N = 4, N = 5, N = 6$. Columns are above: 1.3 –0.5-1.0; 0–0- 1.0. For the first human these numbers are 700, 750; our parameters $N = 5, N = 6$. Columns are changing: 0 – 4.5; 3.0 – 1. If we take into account the beginning of the process, then the column to go up: 0-0.8; 3.0-2.7.

New interesting book is [13] and [23], it is very informative and useful. Interesting new ideas come from physics, which comes with consciousness and genes [24] - [35]. To remind, that our algorithm is on sub-sensorium level.

In the" Manifesto for a Post-Materialist Science" the authors show [25]:

"We are a group of internationally known scientists, from a variety of scientific fields (biology, neuroscience, psychology, medicine, and psychiatry), who participated in an international summit on post-materialist science, spirituality, and society".

"However, the nearly absolute dominance of materialism in the academic world has seriously constricted the sciences and hampered the development of the scientific study of mind and spirituality."

"According to one interpretation of quantum mechanics, this phenomenon implies that the consciousness of the observer is vital to the existence of the physical events being observed and that mental events can affect the physical world. The results of recent experiments support this interpretation. These results suggest that the physical world is no longer the primary or sole component of reality and that it cannot be fully understood without making reference to the mind."

"Many scientists believe a similar transition is currently required, because the materialistic focus that has dominated science in the modern era cannot account for an ever increasing body of empirical findings in the domain of consciousness and spirituality".

Interesting scientific papers published International "Journal of Vortex Science and Technology" [26] – [29]:

"Science pursues truth. However, scientific quest for truth is confined in the frame of a paradigm. Paradigm shift is initiated from unexplainable fact with current paradigm. Quantum science came from the trial to explain the unexplainable fact, black body radiation. 21st century needs new paradigm. New paradigm will be initiated from unexplainable fact. This time it could be water memory. It was revealed that every matter has its accompanying wave. The wave part of the matter contains information and functions like matter. The wave of the matter can be transferred to water physically by shaking or tapping and thus serially diluted water has been used to stimulate natural healing power in traditional homeopathy. We have preliminary data for the cellular level. Data for biological systems will follow".

6. Cubic spline approximation

We have empty segment, which begin with u_0 and finished with u_{N+1}. The unknown values (pulse beats) are $u_i, i = \overline{1, N}, N > 1$. How can we find these values u_i?

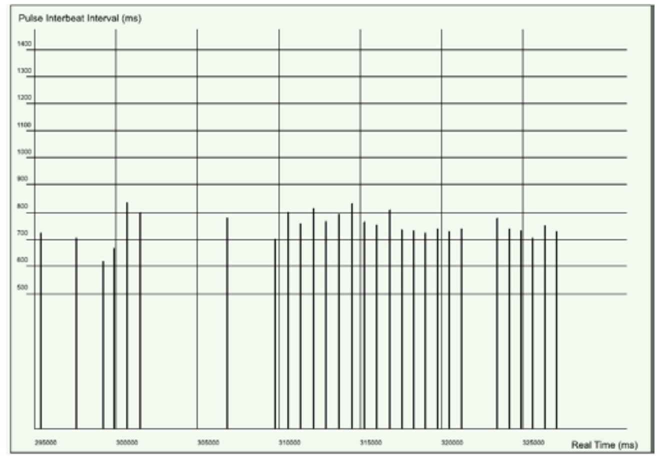

Fig. 8. Heart rate variability fragment with some empty intervals.

In numerical mathematics the traditional way is to approximate this empty interval with spline function [36]. Unfortunately, this problem differs from classical interpolation problem in two points. In numerical mathematics are given the points in which are given the unknown function values. Here we don't have points and don't have the values (heartbeats length). Now this problem can be solved with ideas in the data's from heart rate figure. Here we cannot solve this complex, but we can suggest first simple solution.

The first question is: how many heart beats have we lost? The answer is not clear. The first reason is to make as some middle value of some intervals left and right of this empty interval. This assumption allows us to find $t_i, i = \overline{1, N}$.

The situation with $N = 1$ will be looked separately. The values u_0, u_2 are known. Clearly, we find:

$$u_1 = \frac{u_0 + u_2}{2}.$$

Now we looked at $N \geq 2$. Firstly, we assume that at points t_i we know the values $u_i = u(t_i)$. The first derivatives we designate of the splines as $S'(t_i) = m_i$. For the one segment $t \in [t_i, t_{i+1}]$ then we have this form of the classical cubic spline [36] - [38]:

$$S(t) = u_i + m_i(t - t_i) + a_{i,1}(t - t_i)^2 + a_{i,2}(t - t_i)^3, \quad i = \overline{0, N}. \tag{1}$$

Here we have two unknown coefficients $a_{i,1}, a_{i,2}$. First equation is continuity in next point t_{i+1}:

$$u_{i+1} = u_i + m_i \tau_i + a_{i,1}\tau_i^2 + a_{i,2}\tau_i^3, \tau_i = t_{i+1} - t_i, \quad i = \overline{0, N}. \tag{2}$$

Second equation is continuity of first derivative in the point t_{i+1}:

$$m_{i+1} = m_i + 2a_{i,1}\tau_i + 3a_{i,2}\tau_i^2, i = \overline{0,N}. \quad (3)$$

Third equation will be the continuity of second derivative in the point $t = t_i$:

$$2a_{i-1,1} + 6a_{i-1,2}\tau_{i-1} = 2a_{i,1}, i = \overline{1,N}. \quad (4)$$

We obtain from equations (2), (3) following values for the unknown coefficients:

$$a_{i,1} = 3\frac{u_{i+1} - u_i}{\tau_i^2} - \frac{m_{i+1} + 2m_i}{\tau_i},$$

$$a_{i,2} = \frac{m_{i+1} + m_i}{\tau_i^2} + 2\frac{u_i - u_{i+1}}{\tau_i^3}, i = \overline{0,N}.$$

When substituting coefficients $a_{i-1,1}, a_{i-1,2}, a_{i,2}$ in the equation (4) we obtain:

$$\frac{1}{\tau_{i-1}} m_{i-1} + 2\left(\frac{1}{\tau_{i-1}} + \frac{1}{\tau_i}\right) m_i + \frac{1}{\tau_i} m_{i+1} =$$

$$3\frac{u_i - u_{i-1}}{\tau_{i-1}^2} + 3\frac{u_{i+1} - u_i}{\tau_i^2}, i = \overline{1,N}. \quad (5)$$

This form is used in the numerical mathematics and its applications [36] – [38]. In interpolation theory in the points $t = t_i$ is given known interpolation values $u_i = u(t_i)$. In our case, the length of heartbeats is unknown. We solved this system to unknown values m_i. We use approximations:

$$\frac{u_i - u_{i-1}}{\tau_{i-1}} = \frac{m_{i-1} + m_i}{2}, \frac{u_{i+1} - u_i}{\tau_i} = \frac{m_{i+1} + m_i}{2}.$$

The equation (5) gives:

$$\frac{m_{i-1}}{\tau_{i-1}} + \left(\frac{1}{\tau_{i-1}} + \frac{1}{\tau_i}\right) m_i + \frac{m_{i+1}}{\tau_i} = 0, i = \overline{1,N}. \quad (6)$$

Classical cubic spline have continuous second derivative. To construct spline we need two boundary conditions on both ends of interval. Traditionally are given the first or second derivative. On left side for the first and second derivative, we have:

$$m_0 = m_0^{'},$$

$$2\frac{m_{-1} - 2m_0 + m_1}{t_1 + t_{-1}} = m_0^{''}. \quad (7)$$

Here m_{-1} is the first value before the left side heart rate; the time t_{-1} is for previous heart rate beat. The boundary condition with second derivative we can transfer in following form:

$$m_0 = 0.5m_1 - 0.5m_0^{''}(t_1 + t_{-1}) + 0.5m_{-1}. \quad (8)$$

Analogous the right side boundary condition is:

$$m_{N+1} = m_{N+1}^{'}, \quad (9)$$

$$m_N = 0.5m_{N+1} - 0.5m_{N+1}^{''}(t_{N+2} + t_N) + 0.5m_{N-1}. \quad (10)$$

Similarly m_{N+2} is the value after the right side heart rate m_{N+1} and the time moment t_{N+2} is next after right side time. If the empty interval left or right side contains only one heart beat point, then the formula (6) transform to boundary condition.

We will solve the system (6) together with boundary conditions (7)-(10) with the elimination method Samarskii [40]. We write system in the form:

$$A_i m_{i-1} + C_i m_i + B_i m_{i+1} = 0, i = \overline{1,N}. \quad (11)$$

Here $A_i = \frac{1}{\tau_{i-1}}, B_i = \frac{1}{\tau_i}, C_i = \frac{1}{\tau_{i-1}} + \frac{1}{\tau_i};$

$$m_0 = \kappa_1 m_1 + \mu_1, m_{N+1} = \kappa_2 m_N + \mu_2.$$

$$m_0 = \kappa_1 m_1 + \mu_1, m_{N+1} = \kappa_2 m_N + \mu_2.$$

For the first type boundary conditions, we have such values:

$$\kappa_1 = 0, \mu_1 = m_0^{'}, \kappa_2 = 0, \mu_2 = m_N^{'}. \quad (12)$$

If we have second type boundary conditions, we have values:

$$\kappa_1 = 0,5, \mu_1 = 0.5\left[m_{-1} - m_0^{''}(t_1 - t_{-1})\right],$$

$$\kappa_2 = 0,5, \mu_2 = 0.5\left[m_{N+1} - m_N^{''}(t_{N+2} - t_N)\right]. \quad (13)$$

Now we can give the algorithm for the elimination method [40]:

$$a_1 = \kappa_1, b_1 = \mu_1, a_{i+1} = \frac{B_i}{A_i a_i + C_i},$$

$$b_{i+1} = \frac{A_i b_i}{A_i a_i + C_i}, i = \overline{1,N}, m_N = \frac{b_{N+1} + a_{N+1}\mu_2}{1 - \kappa_2 a_{N+1}}, \quad (14)$$

$$m_i = a_{i+1} m_{i+1} + b_{i+1}, i = \overline{0, N-1}.$$

Mathematically the sufficiently conditions for the stability of the elimination method are Samarskii [40]:

$$|C_i| \geq |A_i| + |B_i|, i = \overline{1,N};$$

$$|\kappa_j| \leq 1, j = 1,2; |\kappa_1| + |\kappa_2| < 2.$$

As we see, the sufficiently conditions are fulfilled. Realized in the algorithm (14) we find the values $m_i, i = \overline{1,N}$.

Now the question is to find the values of lengths of heartbeats. We use the finite difference method [39], [40]:

$$\frac{u_i + u_{i-1}}{\tau_{i-1}} = m_i, u_i = u_{i-1} + \tau_{i-1} m_i, \ i = \overline{1, N-1}. \quad (15)$$

Really for $i = 1$ we have:

$$u_1 = u_0 + \tau_0 m_0.$$

Values m_0, u_0 are known, we can find the value u_1. The first weakness of this approximation is the finite difference order, which is first order of approximation. The second possibility is to go from the right hand side:

$$\frac{u_{i+1}+u_i}{\tau_i}=m_{i+1}, u_{i+1}=u_i+\tau_i m_{i+1},$$
$$i=N-1, N-2, ..., 1. \qquad (16)$$

The value from equations (15) we designate as u_i^l, but from equations (16) as u_i^r. Then as true value, we use arithmetic middle value:

$$u_i=\frac{u_i^l+u_i^r}{2}.$$

We understood that method is first approximation for the reconstruction of the empty interval. We hope to publish improved mathematical method in future. This is good side of such approximation, but weakness of this method is the absence of specific side of structure of heart rate curve character.

7. Conclusion

We have constructed some new form of registration of the time interval between the current and the previous heartbeats and the time from the beginning the registration process. We have some new spline approximation by splines for the reconstruction of lost heartbeats. This allows displaying blank intervals in the drawing. We are offering our new criteria. We believe that our sub sensory criteria determines the processes in living systems. The usage of spline ensures the smoothness of the obtained curve, because the cubic spline has a continuous second derivative. We have idea for extrapolation in the near future, which will explain soon.

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diagnostics, patophysiological mechanisms, correction, criteria and methodology for the creation of a new reflector diagnostic and training methods. Since 1978 scientific investigations of the mechanisms of stress resistance. Have experience in brain studies. Has elaborated an original conception of adaptation to stress, based on psychophysiological reactions of Energy Exchange. Has created original methodology for early diagnostics, prevention and treatment of stress-based dysfunctions by means of cognitive, physical, medical, psychotherapeutic and reflector, non-drug methods; have practical work experience in this field Has caused computerized equipment and more than 30 software programs. Special attention is paid to stress influence on many health problems and its impact on people's quality of life, stress prevention and management. Creates new, original equipment, technologies, training programmer and teaching materials.