signal processing, plethysmography,
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DIAGNOSIS SUPPORT METHOD OF PLETYSMOGRAPHICAL RECORDS WITH THE USE OF FRAMEWORK TENETS

The aim of this study is the processing and evaluating of plethysmographical records giving important information about the blood vessel function. Result of this study is to present the methodology for classifying the records by means of mathematical methods that would contribute to systematic evaluation of what has been found by finger plethysmography. Thereafter the experimental expert system based on framework systems serves to determine the diagnosis on the basis of previous mathematical processing is introduced. The goal of the project was also creation of application by the form of the extension of kernel for the use of framework that is determined for support of control and information systems development in the area of signal processing, elaborate and describe the methodology of extension hereof setting in the nature of specific applications. Beyond above-mentioned outputs the solution of the project should give the specific knowledge about the usage effectiveness of evolutional frameworks. Fundamental implementation idea is based on the usage of MATLAB as the basis for extension of common kernel.

1. INTRODUCTION

The aim of this study is the signal processing and evaluation of biosignals of plethysmographical records using framework programming technique for diagnosis support use.

The finger plethysmography is a noninvasive method for recording pulse waves from fingertips of human extremities. Pulse wave is created by the heart activity and by penetration of blood through the vascular system.

The variability of particular plethysmographical records is rather wide therefore till now the definite criterions that determine limits between physiological and pathological cases have not been established. That is why the analysis of records is a time consuming process and the evaluation is after all subjective and depends on the knowledge and skill of physicians. The aim of this study is to find out the most used methods of evaluation of plethysmographical records. And also is to show a way for evaluation with the use of new methods of processing with the help of computer and new mathematical methods.

Program orientated frameworks offer very efficient tool for realisation of applications on the basis of graphical notation which gives evaluation or control of the model problem.

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Frameworks provide us the possibility of simple and quick extension of solution contemporarily existing data class which is the integral part of software development applications.

2. EVALUATION UNTIL NOW

Evaluation of pulse waves was made by a skilled physician visually or with the help of common used criterions. Some of those criterions did not take into account the possibility of a change of pulse frequency during examination and that is why the error in reading of pulse wave parameters arose. The error was larger for more quick pulse frequency. The advantage was to use criterions, which express the ratios of individual parameters of the pulse wave. We used such parameters, which could better define relations between single parts of pulse wave and limit the influence of the change of pulse frequency and magnitude of amplitude.

The parameters ratio between peaks distance of pulse wave could easier determine the location placement of particular parts with respect to the magnitude of pulse wave, which could be at every single measurement variable. (Fig.1)

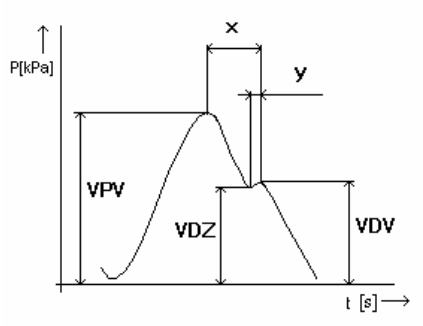

Fig.1: The parameters of pulse in single wave

3. THE NEW LOOK ON EVALUATION

The advantage of this evaluation is a new look on the pulse wave in whole not only on it's parts. The most effective method nowadays is Fourier's transformation.

In this area the evaluation is orientated more on comparison of records obtained from big number of measurements done for many patients of the same category of findings of evaluated records. That means that on particular frequencies the amplitudes of the respective records are compared.

The experienced physician (expert) during the analysis of pulse wave in time domain decides about the possible pathological findings and will put them into groups according to the kind of illness.

The infliction of vascular system will be characterized by amplitude expansion on particular frequencies that have been created from groups of spectrum of the same type of damage. The evaluation of measured records will be done by comparison of the amplitude range with amplitude expansion of individual groups of findings.

The actual study of the evaluation of plethysmographical record enables to give criterions in frequency domain. These criterions represent from the first to the forth harmonic parts of amplitude spectrum of the signal. The larger the group of patients is examined in this way the more exact ranges among particular groups are.

4. PREPROCESSING OF RECORDS WITH USE OF THE WAVELET TRANSFORMATION

Nowadays wavelet transformation, which serves before all for time frequency analysis of data and generalization of filtration, is very often used. It provides also some further possibilities such as compression of data with a little loss of the information value. Because we need to store patient's records from every measurement for long time the problem with the data saving arises because the data capacity is very large.

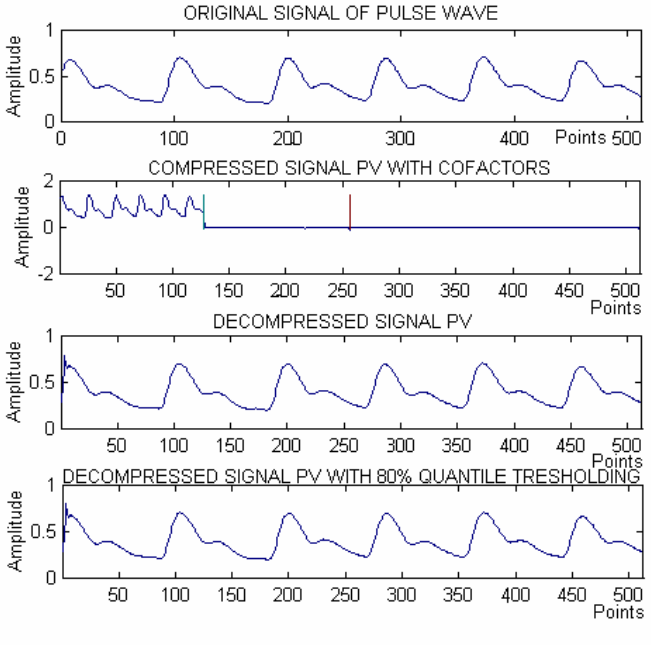

Fig.2: Example of signal processing by wavelet transform

To verifying of proceedings at application wavelet transformation was programmed testing toolbox in the program MATLAB and we used it for performing necessary calculations. The transformation was applied to a signal of pulse wave with the characteristic vector with the length 512 (Fig.2).

Wavelet transformation was applied to the signals with the following bases:

- Daubechies : D2, D4, D8
- Haar : H1, H4
- Walsh - Paleye : W-P2, W-P4

Many wavelets bases exist which one can use for transformation, but for correct analysis it is necessary to have orthonormal bases.

Wavelet transformation causes decomposition on signal components. The result of the transformation is a signal with the length of one half of original signal and cofactor is the same length.

From Fig. 3 we can find out that when we use the Daubechies transformation base the partial deformation of the signal appears after the reverse decompression before all at the grade 2 which is caused by the fact that coefficients are tabulated as approximate values. At the compression and decompression was the transformation matrix corrected in such a way to suppress the periodicity of signal as it is shown in the first two lines of the figure.

Results of decompression with the use Walsh-Paley and Haar's base are the same as at the base H1 - remained energy = 100 %, maximum error and standard deviation is in the rule 10^{-33}, this error is caused by around numbers during the calculation on the computer.

If we execute transformation of signal pulse wave with the use of Daubechies base we obtain the signal nearly the same signal as before the transformation, what we can verify by comparison of both signals.

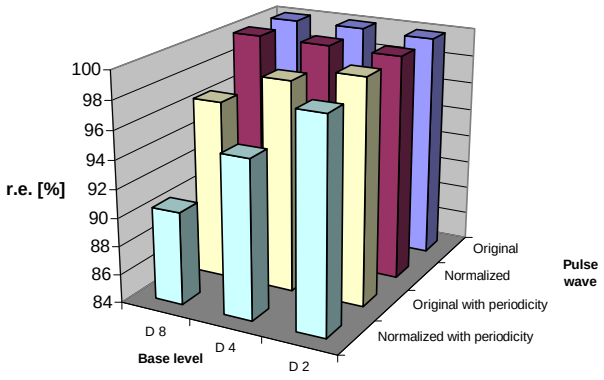

Fig. 3: The values of retained energy (r.e.) at the compression of a pulse wave on the one quarter of its original magnitude at the use of Daubechies bases

The pulse wave compressed on one quarter of the original signal has the same amplitude spectrum and we save remarkable part of capacity for storage of data files and we also save time necessary for calculation FFT. (Fig. 4)

If we want to save the original signal unchangeable we must to save after the transformation the information about the cofactors too.

Even here we need to save disk space for data storage by the suitable zero setting (filtration) of cofactors.

At the filtration we put zero setting on some values of cofactors and for reverse transformation - decompression only dominant values. More methods for zero setting exist: quantile, hard, soft etc.

After this test we can tell if we choose the suitable base for example Daubechies 2 we can at quantile tresholding 100 % value of cofactors and reverse decompression remain 99,86 % of

energy. For saving of signal is enough for us from the original 512 values to save only 128 (compressed signal) plus 0 (cofactor) , it is together only 128 values.

On Fig. 2 are shown the results of quantile tresholding of pulse wave signal with the length 512 values which was compressed and decompressed by the wavelet transformation by the base Daubechies 2.

From the introduced results is visible that the most appropriate is Daubechies base. We can make a conclusion that it is possible to use for analysis of the spectrum compressed data and to save the time which we need for decompression

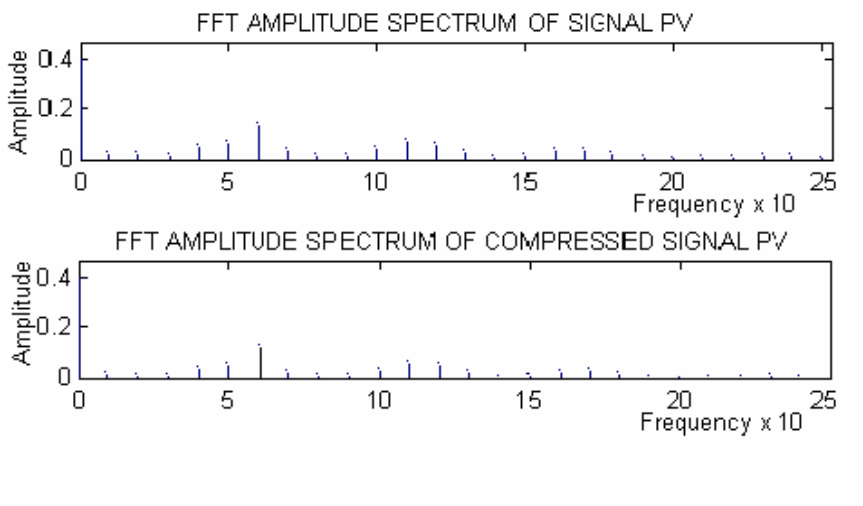

Fig.4: Comparison of PV spectrum after the wavelet transformation

5. COMPLETE EVALUATION BY EXPERT SYSTEM

The expert system creates the entire elaboration of plethysmographical records and it is able to simulate the work of doctors at the determination of diagnosis.

In the final summary the evaluation by the expert system will include the evaluation in time domain with the help of existing and supplementary criterions and it will contain the evaluation of parameters obtained during the evaluation in frequency domain.

The experimental testing of the proposed expert system for support of diagnoses on the basis of analysis of plethysmographical record has been done by problem orientation fuzzy rule based interactive expert system LMPS v 3.02 (Linguistic Model Processing System).

The problem orientation fuzzy model system LMPS is done on the basis of expert evaluation of real data measured during analysis of real plethysmographical records and supplemented with diagnosis declared by the doctor. At present the system is able to recognize two chosen diagnoses II and I.

The set of 28 measurements has been used for testing this method.

Experimental verification of diagnostic effect of suggested method for evaluation of plethysmographical records has been done on four real records.

These test records serve for verification of predicative abilities of suggested bases and for verification of estimation accuracy of diagnostic effect.

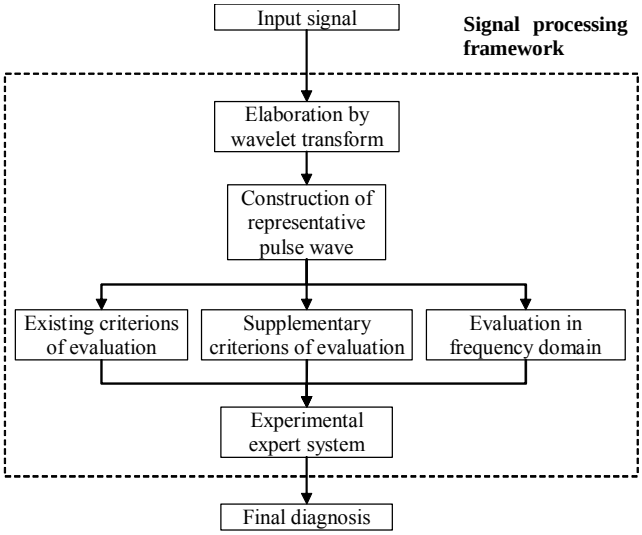

Fig.5: Model of signal evaluation using framework.

The expert system proved good results (Tab.1). The size of patient's group influenced the number of output diagnoses. Not all-possible diagnoses have been found because they had not occurred in the considered group of patients.

Tab.1: Rate of possibilities of expert system outputs for particular bases

record number	Sig. Proc. framework		Diagnosis of physician	Results agreement
	I	II		
1	1	0	I	OK
2	1	0,5	I	OK
3	0	0,9	II	OK
4	0,17	0,83	II	OK

6. CONCLUSIONS

To make evaluation of plethysmographical records more accurate leads to an idea to create the systemic apparatus for evaluation of pulse wave. In order that filtration and storage of modified signal was taken an advantage of possibilities of the new mathematical means and the final conclusion was made by expert system based on framework programming.

This method has been already successfully proved on the small tested group of people. But we need to perform more explorations on larger group of patients to find the answer to the question if this method is really effective for elaboration of correct diagnosis, monitoring of a development of diseases of the vascular system and effect of the treatment.

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