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## MODEL OF CTG APARATUS IN LABVIEW ENVIRONMENT

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**Abstract.** *Cardiotocography is now a standard procedure determining the well-being of the fetus. In today's increasing popularity of IoT, there is a need for solutions providing mobility, while maintaining reliability. The article presents the methodology of creating CTG apparatus model, which enables filtration and detection of the basic parameters of the examination.*

**Key words:** biomedical equipment, biomedical signal processing, biomedical electronics, telemedicine, digital signal processing, internet of things

### MODEL APARATU KTG W ŚRODOWISKU LABVIEW

**Streszczenie.** *Kardiotokografia jest obecnie standardowym badaniem określającym dobrostan płodu. W dobie coraz większej popularności IoT potrzeba rozwiązań zapewniających mobilność, przy jednoczesnym zachowaniu niezawodności. Artykuł przedstawia metodykę tworzenia modelu aparatu KTG, który umożliwia filtrację, oraz detekcję podstawowych parametrów badania.*

**Słowa kluczowe:** sprzęt biomedyczny, przetwarzanie sygnałów biomedycznych, elektronika biomedyczna, teledycyna, cyfrowe przetwarzanie sygnału, internet rzeczy

### Introduction

Nowadays, the Internet of Things (IoT) is one of the most rapidly growing fields of technology. The term Internet of Things was first used by British expert of new technologies – Kevin Ashton [9]. The IoT devices are present in almost every field, such as marketing, industry, transport, building management systems, environment or medicine.

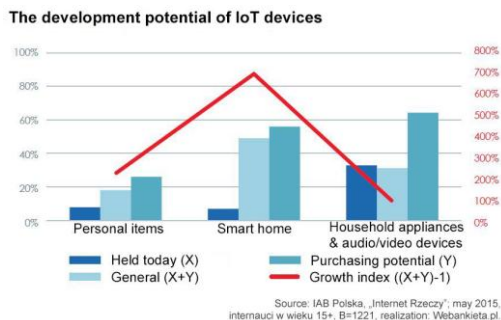


Fig. 1. Development potential of IoT devices [7]

The concept of the IoT may, in a simplified form, be explained as the ecosystem, in which items equipped with sensors communicate with computers. This solution has found a considerable amount of applications: smart home devices, building automation, smart cities or defense systems. All these systems work according to the following principle: the items equipped with sensors communicate with the external devices via wireless network. The external device processes the signals and analyzes them according to the pre-defined criteria [2].

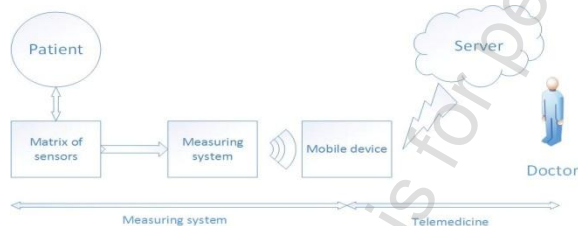


Fig. 2. Block diagram of measuring system in telemedical application

It can be observed, that the telemedical systems are as well moving towards the wireless sensors with functionality similar to the one of sensor solutions of the IoT. Thanks to such technologies, patients do not have to be present at the medical facility during examinations or test. In medicine, this solution grants more autonomy and makes the service personalized. In addition, the medical facilities shall be able to minimize the expenses by using digital medicine solutions. The examples of such solutions are: blood glucose meters, capsule endoscopy (camera pills) or electronic tattoos [6]. Also the CTG apparatus equipped with set of specialized sensors can be included in above solutions.

Cardiotocography (CTG) is a combination of cardiography and tocography, the latter being older field. The basic parameters measured with this method are: fetal heart rate (FHR), oscillations, acceleration, deceleration, tachycardia, normocardia and bradycardia. The traditional CTG examination is performed with cardiotocograph, also known as an electronic fetal monitor (EFM). The device uses Doppler ultrasound method, where fetal heart rate can be described after the analysis of the difference between the waves sent out and the ones that bounced back [10].

The main drawback of the above mentioned method lays in its invasiveness. The number of scientific publications implying that ultrasounds may pose danger to the fetus by causing hearing damage, is increasing [2].

### 1. Work environment

The model of CTG apparatus was made in LabVIEW environment. This program is known from its flexibility and clarity of G (graphical) language. Furthermore, it is a great choice for development of signal processing, due to the possibility of data preview in real time. It was chosen also because of large amount of filters ready to be implemented, and significant flexibility of development process.

According to the established measurement scheme, the acoustic waves emitted from fetus heart are captured by piezo film sensors, filtered and processed by filtering module of LabVIEW environment.

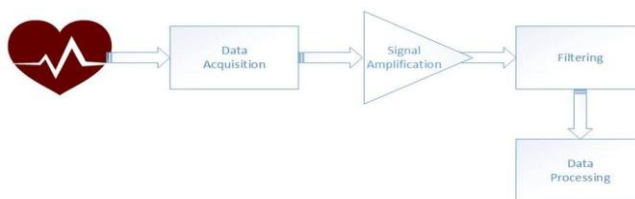


Fig. 3. Stages of acquisition and signal processing

### 2. Model description

The main goal of model development was to create a filtering system, which would reduce the noise made during a CTG measurement, with satisfactory results. Because of that, it would be implemented in embedded system.

The model contains the following modules: filtration of random CTG signals using wavelets and extraction of typical determinants of fetus pathology in CTG examinations – tachycardia and bradycardia.

The results from classic ultrasound method were used as reference signals. They are stored in the database of Technical University of Prague and University Hospital in Brno, as well as shared through PhysioNet site [8]. The main goal of application of exemplary signals was to choose the best filtering system based on wavelet transform. To verify its effectiveness, a random noise generation was used, which in the best way imitates the environment of fetal heart rate propagation.

### 2.1. Import of the exemplary signals

The first step is to load the signal using *Read from CSV* structure (Fig. 4).

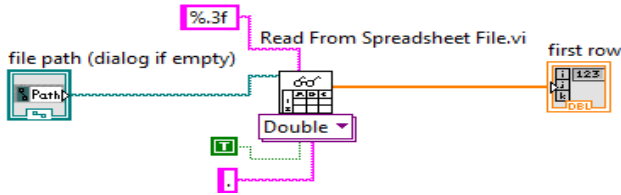


Fig. 4. Read from CSV structure

The core of a structure is *Read from Spreadsheet File* block. After definition of path to the input file, spreadsheet is imported and converted to 1D Array.

### 2.2. Random noise generation module

Next stage is to generate noise which in the most realistic way will imitate noise made either in environment in which fetus is placed, and during signal acquisition (ex. movement of piezo sensors). The core of the system is *Periodic Random Noise* block [3]. It generates values oscillating around input signal, which creates random noise (Fig. 5).

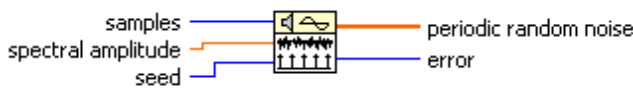


Fig. 5. Periodic Random Noise

In this case, it will be an exemplary signal. The effect of noise implementation is received by adding a *Build Waveform* block (Fig. 6).

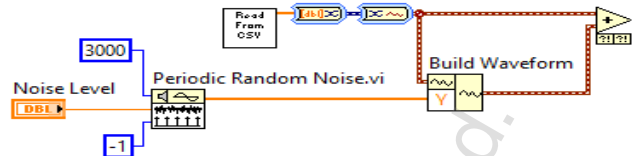


Fig. 6. Noise generation

### 2.3. Filtering module

The most important part of developed model is *Wavelet Denoise* structure, which uses wavelet transform. It is the best solution in case of filtering biophysical signals.

After carrying out tests, the orthonormal 6<sup>th</sup> level Daubechies wavelet was chosen due to its shape, which is very similar to CTG signal. The choice of this wavelet is justified by a compromise between accuracy of filtering process and computational load of the processor. It is also used in case of ECG signal [1]. Daubechies Wavelets belong to group of orthonormal wavelets specifying a discrete wavelet transform and is characterized by a maximum number of vanishing moments. Every level of wavelet possess a scaling function which generates an orthonormal analysis on many levels of resolution. Wavelets are widely used in resolving problems such as: discontinuity of the signal, or image processing.

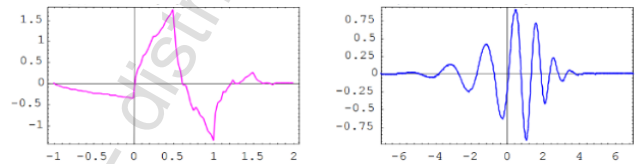


Fig. 7. Daubechies wavelets: 2<sup>nd</sup> and 12 level

In reality wavelets are not used but filters related to them. On each level of decomposition, low and high pass filtering is performed. In LabVIEW environment, it is maintained by *Wavelet Denoise* structure.

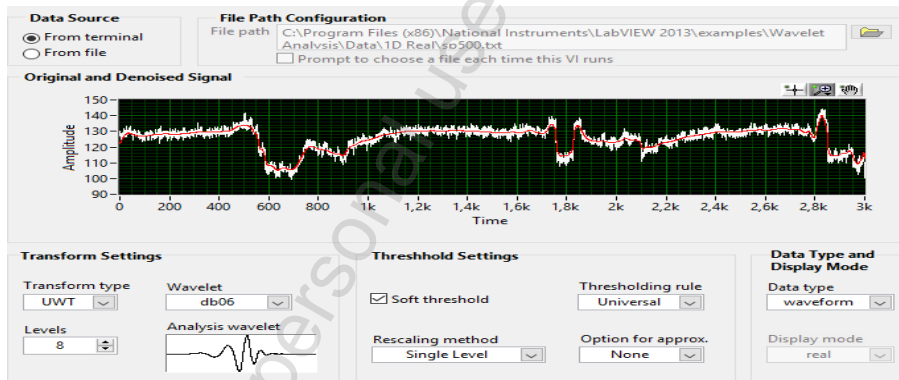


Fig. 8. Interior of Wavelet Denoise structure

According to the fact that the curve was created using thresholds, the program is interpreting them as separate graphs. This problem was solved using developed structure called *Monotonicity Check*. In the first stage, it is necessary to define a place in which a change of threshold is detected. Presented solution suggests using the *Feedback Node* block, which saves the values of previous cycle of data processing. Next, through using *Not Equal?* block, the boolean value is received dependent on comparison of the previous and present result. According to output value, signal is processed without any change (False case), or it is assigned to the previous threshold (if the function is increasing) or next (if the function is decreasing).

### 2.4. Tachycardia and bradycardia detection module

After filtering process, it is necessary to extract the basic parameters of CTG examination. In proposed solution input signal was divided into 4 sub-thresholds and then shown as graph.

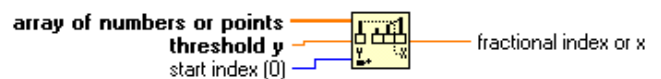


Fig. 9. Threshold 1D Array

### 2.5. Testing of filtering module

After development of filtering module, the tests were carried out to verify proposed solution. They were made by implementing noise, on exemplary signal, with preset spectral amplitude. Next, the signal was filtered and then compared to the original one. The results for test with spectral amplitude equal 0.2 are as follows.

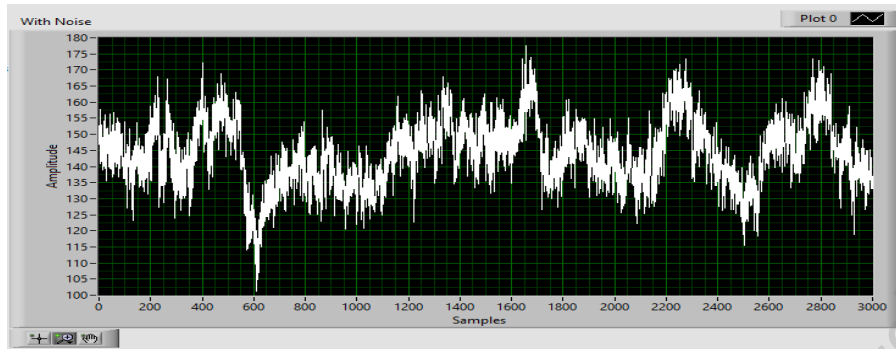


Fig. 10. Signal with implemented noise with spectral amplitude 0.2

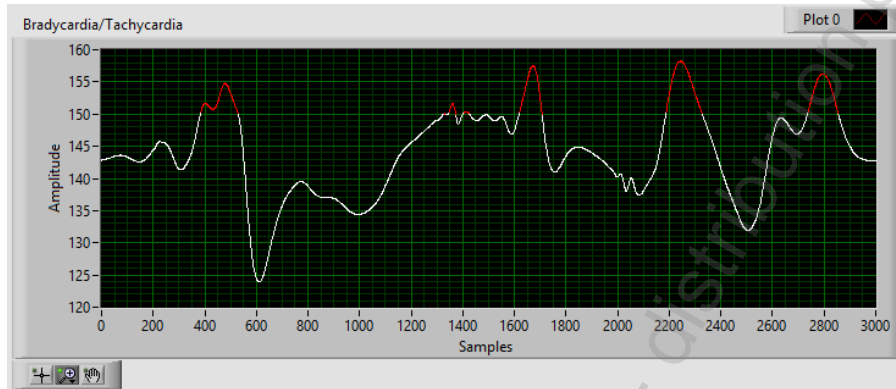


Fig. 11. Filtered signal

### 3. Laboratory tests

The last step was to carry out laboratory tests. They were made through generation of exemplary signal using NI 9263 [4] and piezoelectric transducer, which acts as vibroacoustic generator. Next, the signal was captured by SDT1-028K piezo film sensor [5] and forwarded to amplifier.

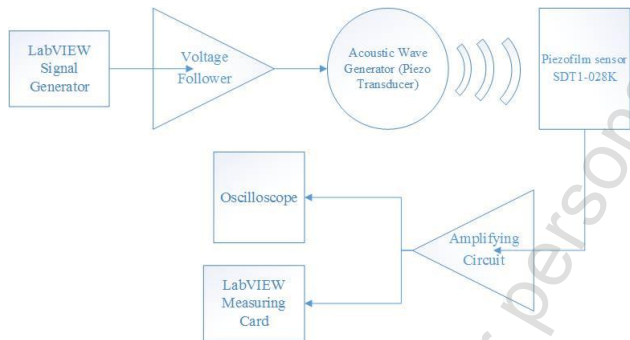


Fig. 12. Schematic diagram of laboratory station

First, it was necessary to check the correctness of generated signal through its observation oscilloscope.

Next, after saving the curve into file, it was possible to process it in LabVIEW environment. Previously developed filtering system, which was based on Daubechies wavelet, was implemented.

### 4. Summary

The use of LabVIEW environment with ADC input systems significantly simplifies and accelerates prototyping new devices, in which, in addition to automatic measurements, complex calculations associated with data processing methods used in real time are necessary.

In the presented model of CTG apparatus, a particular attention was paid to signal filtering and its further analysis. The developed model in satisfying way simulates the environment of real CTG measurement, which also allows to perform preliminary analysis of the results through bradycardia and tachycardia detection. The results of the work will be used to develop a project of CTG apparatus based on BLE device made in technology of the Internet of Things.

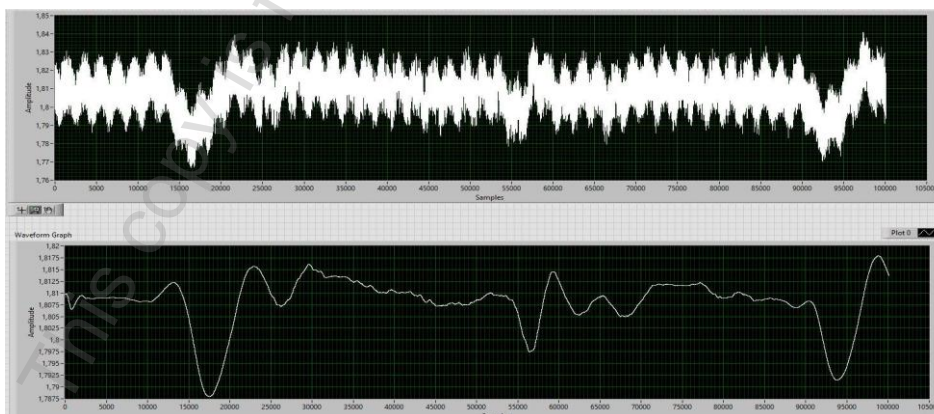


Fig. 13. Signal after acquisition and filtration

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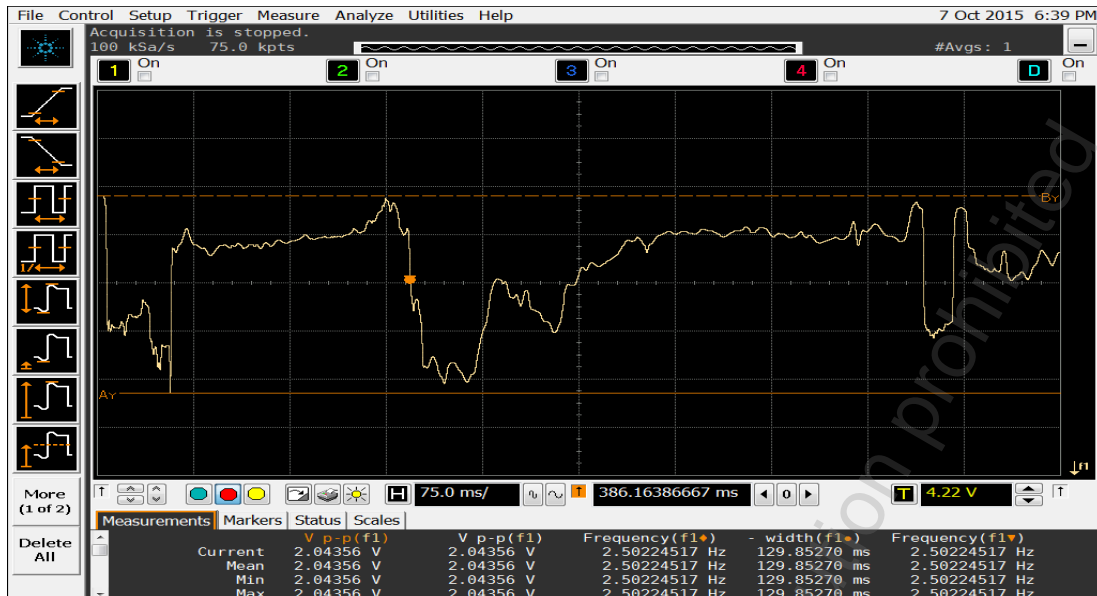


Fig. 14. Generated signal after amplification

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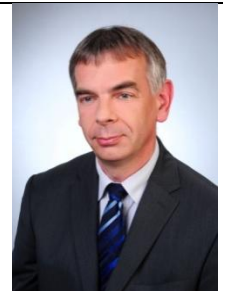
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