

AKADÉMIAI KIADÓ

Processing and analyzing psychophysiological data using NI DIAdem software

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ABSTRACT

The research team has developed a complex system that is capable to record and analyse various psychophysiological data. This article represents the program created in NI DIAdem which can automatically identify illnesses and generate reports based on the input and saved parameters. The created program can import data from different types of file formats. It is converted and saved in a new standardized format for further processing. It can play-back the processed data synchronized with adjustable speed, and visualize them on customized display areas. It can analyse the data based on the input parameters and the pre-defined mathematical equations. The program displays the input and calculated parameters, the results and the detected illnesses on automatically generated reports.

ORIGINAL RESEARCH
PAPER



KEYWORDS

psychophysiological, analysis, DIAdem, ECG, EEG, national instruments, VBA script, report, illness detection

1. INTRODUCTION

Psychophysiological data is that special kind of data of the human body that can be used to infer psychological behaviour.

The research team has created an expert supporting system. This system records and analyses different psychophysiological data like the electroencephalograph (EEG), electrocardiograph (ECG), saturated muscle oxygen (SMO₂), Total Haemoglobin (THb) and Arteriography data. A decision tree was implemented to provide the measurement system with an output that can be reported as a diagnostic result. Its inputs are the various heart rate values (Max., Min., SD1, SD2, pNN50) and are used to determine upper respiratory problems, diseases, long-term fatigue and digestive problems. From the SMO₂ it can conclude to sympathetic and parasympathetic fatigue. And the Arteriography parameters are used to screen for optimum resting time of the heart, aortic pulse wave velocity, or if non peripheral resistance is increased. Stitching these sentences together they will be displayed on the last tab of the interface and pasted at the end of the report. This paper is part of a larger research project, further results will be published in [1, 2].

The voltage difference between the electrodes placed on the human scalp, which varies with time, is measured. These can be used to test the actual state of the human brain or the psychological state of the subject. During EEG examinations, the potential difference between two electrodes is measured. The measurements can be bipolar, when the curves recorded at two different points in the skull are evaluated relative to one another and they can be unipolar when the potential changes are compared to an indifferent or inactive electrode [3].

EEG examinations are often supplemented by additional physiological examinations, which provide a more accurate and comprehensive picture of the actual and psychological state of the human body and brain.

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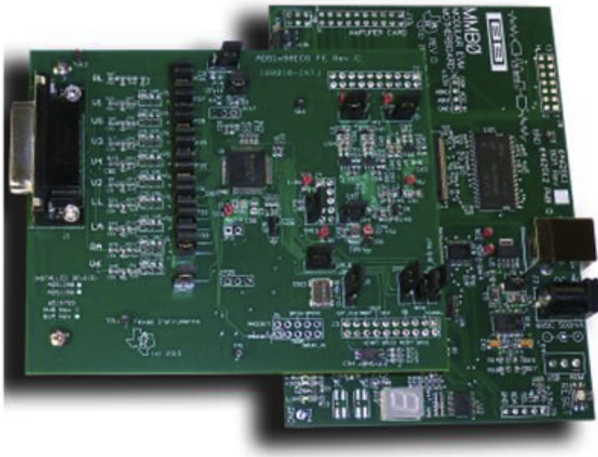


Fig. 1. The ADS1298ECG-FE data acquisition card [8]

ECG is a non-invasive diagnostic procedure that provides information on the functioning of the heart, examining its electrical effects by recording changes in the electrical voltage produced by myocardial contraction.

The heart is examined using limb and chest electrodes. The axes of the frontal plane are represented by the electrodes of the limb, while the axes of the horizontal plane are represented by the thoracic electrodes. For general measurement, 4 limb electrodes are used, from which the ECG instrument generates 6 leads (I, II, III, aVF, aVR and aVL), supplemented with 6 chest electrodes, from which it also produces 6 leads (V1, V2, V3, V4, V5 and V6). Each lead can see the heart from different angles. The 12 leads can be considered as sufficient for a general inspection [4–6].

The waves and peaks detected on the ECG are: P, Q, R, S, T. Each wave represents an electrical discharge or electrical charge of a specific part of the heart [7].

2. RECORDING OF RAW PSYCHO-PHYSIOLOGY AND PHYSIOLOGICAL DATA

An ADS1298ECG-FE data acquisition card was used to record the ECG signals. The card is specially developed for recording and amplifying ECG signals (Fig. 1).

The brain signals are captured using a Muse EEG device. The device is sold by InteraXon, which is commercially available for purchase. It is capable to record raw EEG data, raw spectral data, raw acceleration measurement data and power. In addition, it is capable to detect special movements like blinking or closing the jaw [9, 10].

Other devices are also used during the measurement. One of these is the Moxy monitor muscle oxygen level metre, which records and sends the patient's SMO₂ and THb values during the full measurement. Moxy is complemented by two thermometers, one of which is fixed to the skin surface and the other serves as a reference and measures the ambient temperature. The other sensor unit is an Arteriography, which performs a separate measurement in

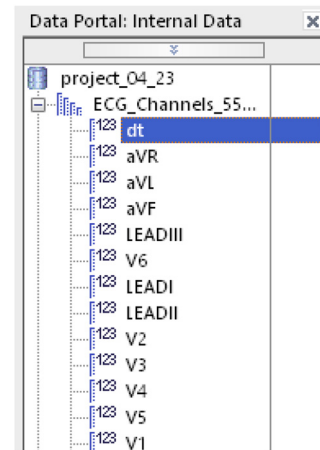


Fig. 2. The interface of the Data Portal

that it is not active during the six-minute data acquisition, but immediately afterwards, and sends parameters related to blood pressure and vascular stiffness [11–13].

3. IMPORTING DATA TO NI DIADEM

Files with the raw.CSV (Comma Separated Values) extension can be easily imported into the NI DIAdem Data Portal interface. By browsing and dragging the raw file into this area, the channels and their details are displayed. The data can also be loaded using scripts. This allows us to use data from a predefined source and file name in our work. The Data Portal interface is shown in Fig. 2. You can also rename, group, and modify various parameters of each file. These can be done manually or with the scripts mentioned earlier.

4. THE OVERVIEW SURFACE AREA

In order to simplify data processing and transparency, we have the ability to create overview interfaces. The amount, position and size of these can be customized. These types are shown in Fig. 3.

The detailed overview of the interface created by the research team is shown in Fig. 7. LEAD I-II-III leads are

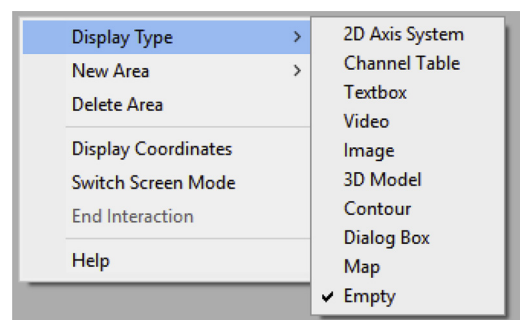
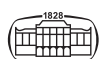


Fig. 3. Types of overview surfaces



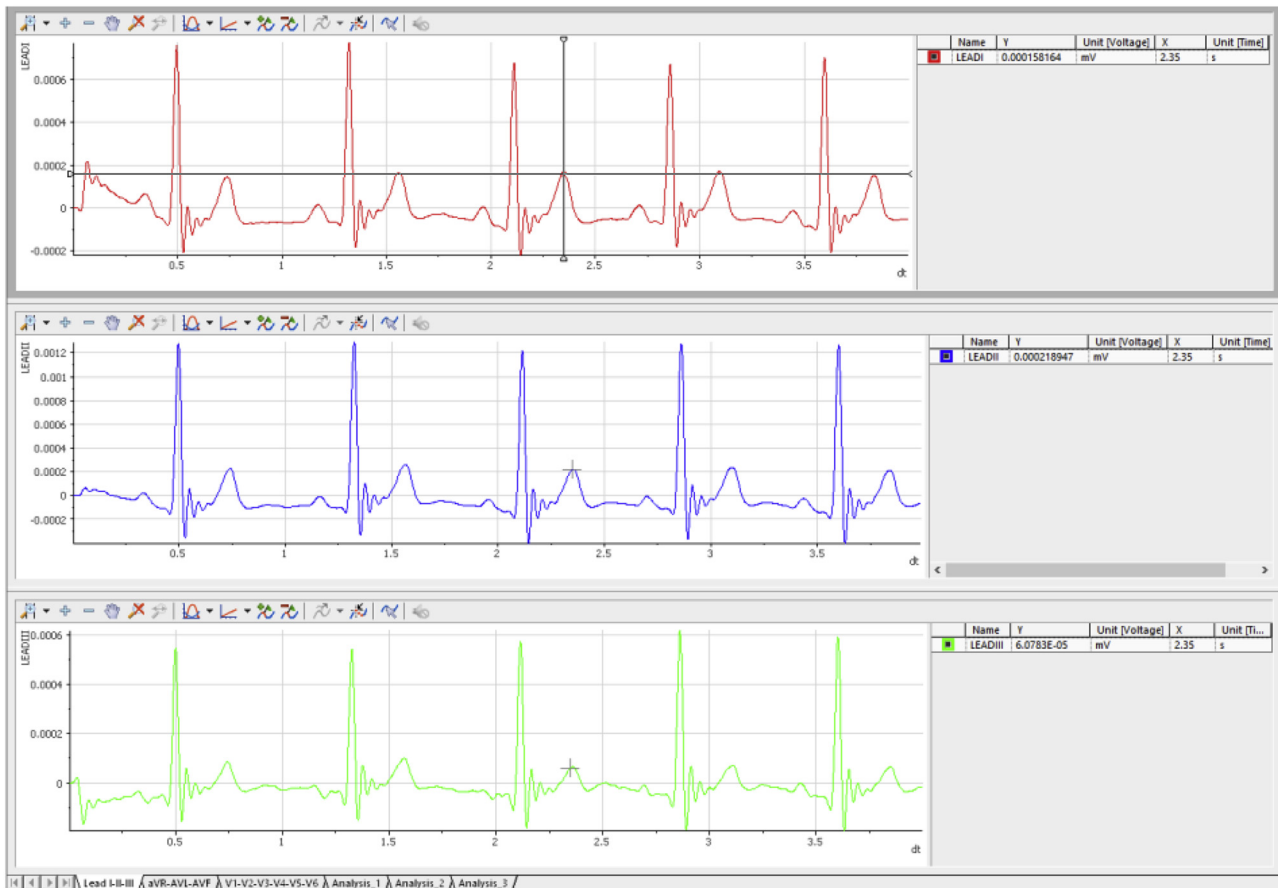


Fig. 4. Overview interface: Display of the Lead I-II-III leads

shown on this. The measured voltage values on the Y-axis are shown in [mV] and the time values on the X-axis are in [s]. The interface facilitates the visual inspection of each wire, since different values can be seen at the same time.

It is possible to play this data in sync. In this case, the data is displayed at a present speed. Various data formats can be synchronized. In addition to speed, you can set various parameters, such as the start and end points of playback, or synchronize different cursors.

With an overview surface, we have the possibility to highlight special points on the charts that can be used later in the analysis. The magnification can be changed dynamically or manually, so it can always be adapted to the actual needs (Fig. 4).

5. BUILT-IN ANALYSIS FUNCTIONS

Raw data can be analysed using built-in, predefined algorithms. These can be accessed through the NI DIAdem Analysis interface. There are simple mathematical operations such as addition, subtraction, division or multiplication. However, more complex mathematical operations such as Fast Fourier Transformation (FFT) analysis, matrix transformations, or regression lines are also available. You can even add your own formulae, as the program can handle

matchscript as well. This way the analyses can be combined with pre-built and user-created mathematical operations.

6. PEAK ANALYSIS

Automatic peak detection allows you to analyse the values measured on different wires. Thus, the position and number of QRS complexes can be accurately determined. This allows the R-R peaks to be fitted to a curve and the data measured on the given lead to be displayed simultaneously. The number of R-R peaks are equal with your heart rate in normal case. When using the analysing function, the input parameters were the measurement time and the voltage measured on the given lead. The selected interval width value is 3 and the lower limit value is 0.0005. With these settings, only the R peaks are highlighted in the QRS complexes (Fig. 5).

7. MAKING SPLINE FOR R-R PEAKS

Heart rate variability allows non-invasive analysis of cardiovascular regulation. The heart rate and pulse rate slow or accelerate at a given moment, according to your current need, depending on how much blood is required for your

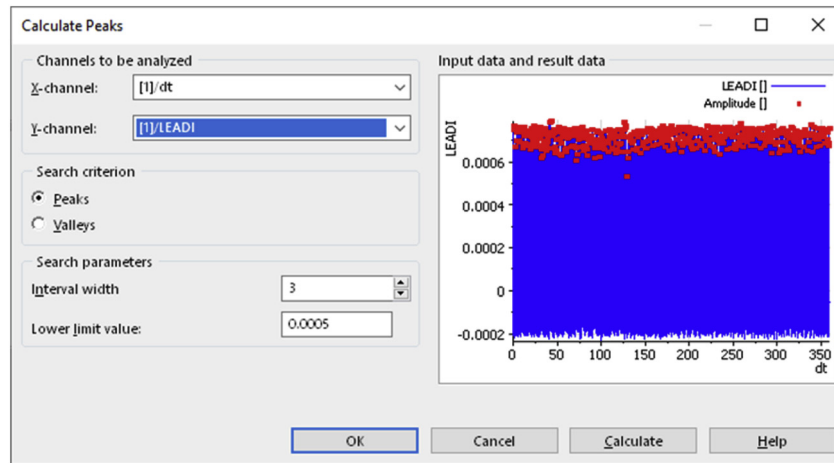


Fig. 5. Peak detection function

body. Extremely low or high values can be a symptom of various diseases. Sympathetic nerve stimuli accelerate, parasympathetic nerve stimulation slows the heart. Volatility is the ability of the heart to follow the needs of the body. The greater the variability, the greater the flexibility and immediate adaptability of the heart (Fig. 6).

The wave fitted to the R-R peaks and the spline curves fitted to it are shown in Fig. 7. The “LEAD I” is shown on the top graph and the “LEAD II” is shown on the bottom graph. The spline function approximates the change in average heart rate. This identifies the willingness to change your heart rate.

8. HISTOGRAM CREATION FOR HEART FREQUENCY

Built-in analysis features include histogram generation. The actual heart rate can be analysed in frequency range. During

the analysis it is possible to specify in how many measurement ranges we want to examine the frequency of the values. Frequency can be measured in absolute terms when determining the exact number of values, or in relative terms when a percentage distribution of individual values is obtained (Figs. 8-9).

9. ANALYSIS OF EEG WAVES USING FFT

NI DIAdem offers built-in analysis capabilities for analysing imported raw EEG data. The analysis is based on FFT, which allows the transition from time range to a frequency range for further analysis of the data.

The analysed data can be displayed and played synchronously. This makes it easier to compare data measured across different channels. Special points and sections can be selected on the chart for further analysis.

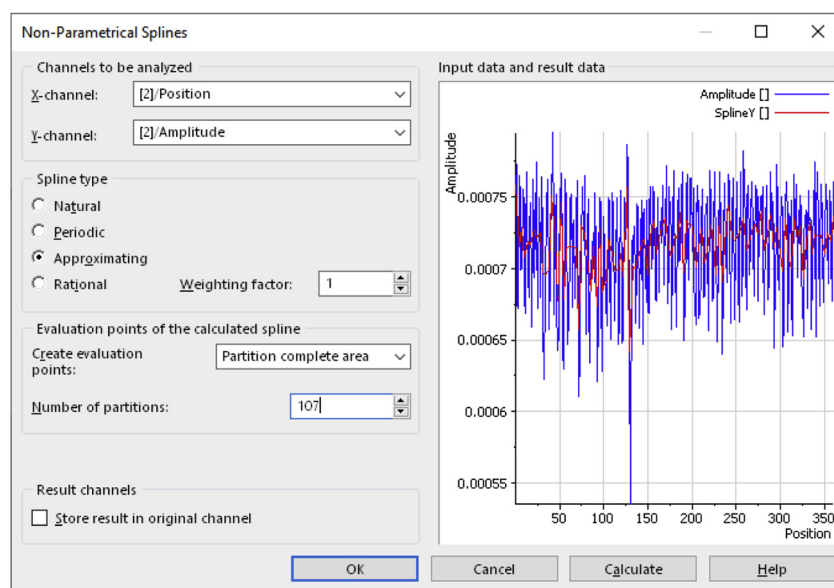
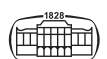


Fig. 6. Non parametrical spline created for the R-R peaks



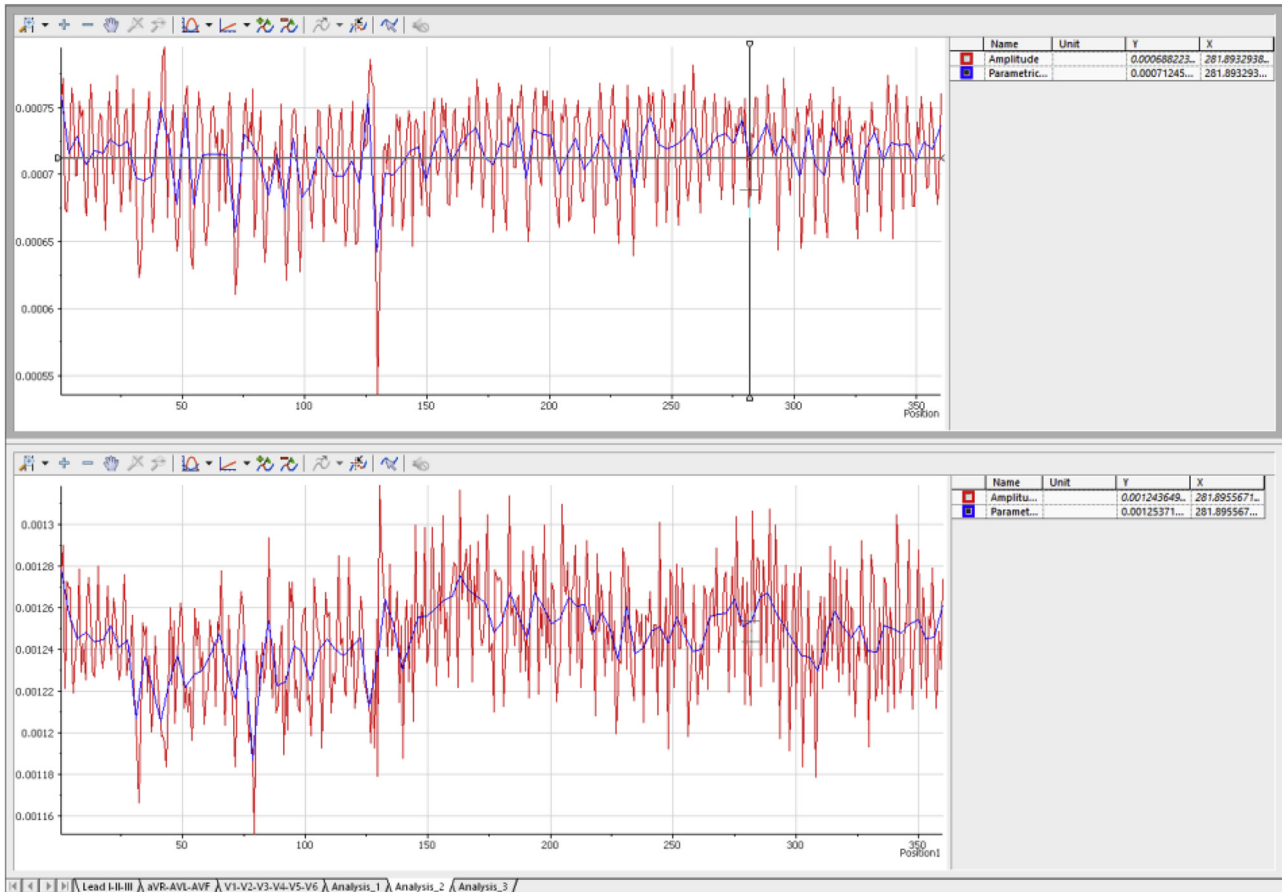


Fig. 7. Display areas for the splines and R-R peaks

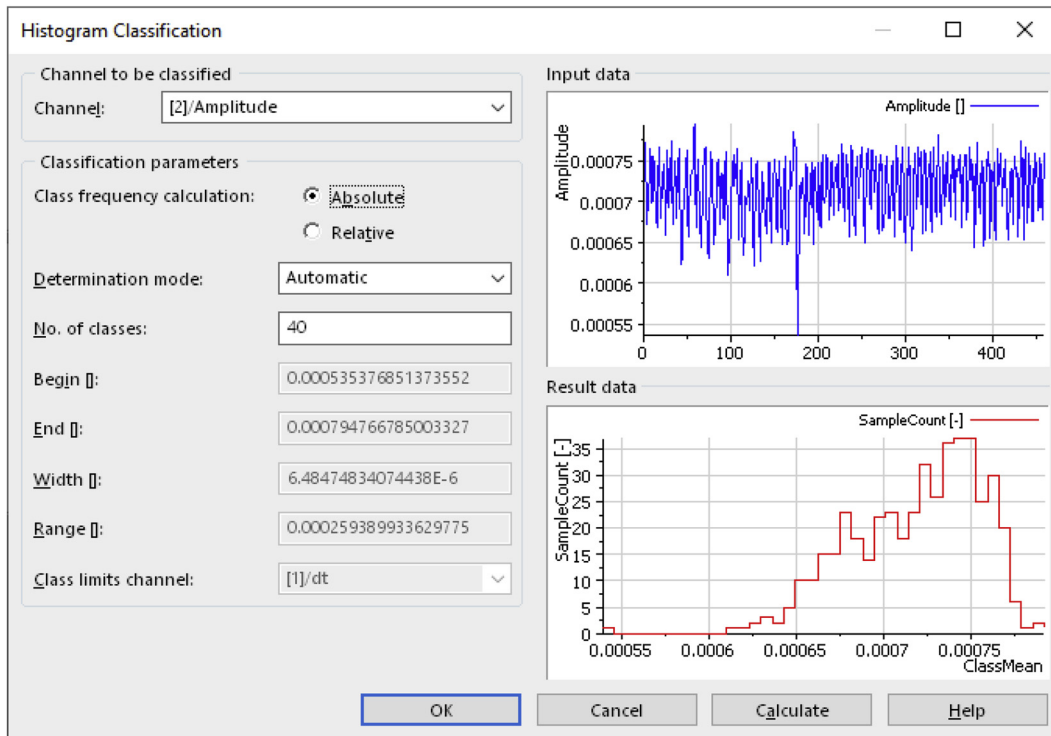


Fig. 8. Histogram classification for heart rate

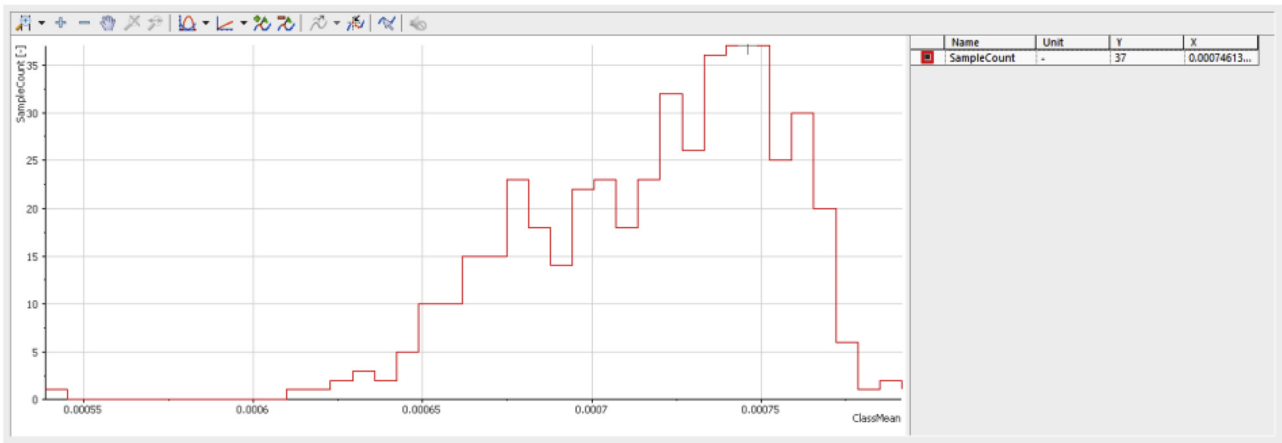


Fig. 9. Display area for the histogram

FFT analysis allows spectral analysis of data. The Y-axis shows the density of the spectral power [V²/Hz] and the X-axis shows the frequency [Hz]. In this way, brainwave types within each frequency range can be identified and their frequency analysed. These data can be used to assess psychological status. It can be used to determine fatigue levels, along with certain parameters (Figs. 10–11).

10. DATA PROCESSING, EVALUATING AND REPORT GENERATING SCRIPT

The script developed by the research team can be divided into two main parts. A high-level flowchart of

the program section that is the main unit of the program is shown in Fig. 12. After the start button, the program starts. The first section is the “User Dialog Box”, where you can enter certain input parameters. The script then checks that they are correct. If the data is incorrect, the “User Dialog Box” will reappear as long as the parameters are correct. The program then continues and then finishes.

Repeated appearance of the interface is part of the error handling. This avoids mistakenly executed analyses, saving time and resources for the user.

The User Dialog Box section is a completely separate script that is part of the main program. Communication between the two programs is facilitated by global variables that can be applied from both parts of the program.

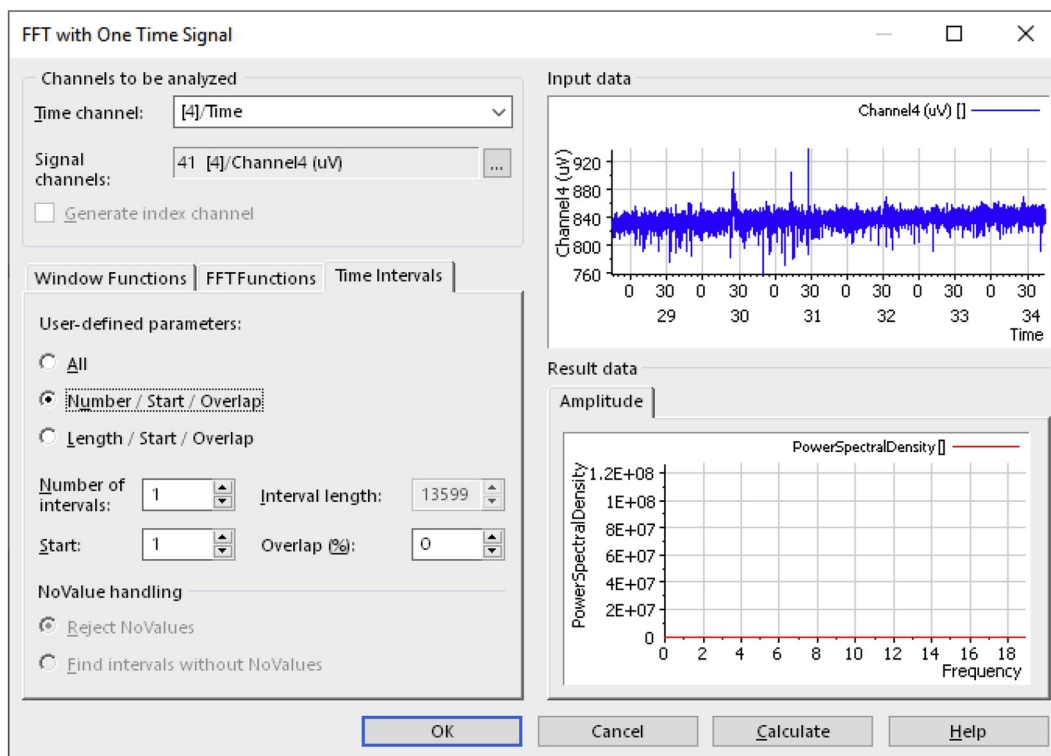
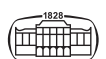


Fig. 10. Fast fourier transformation analysis for the EEG waves



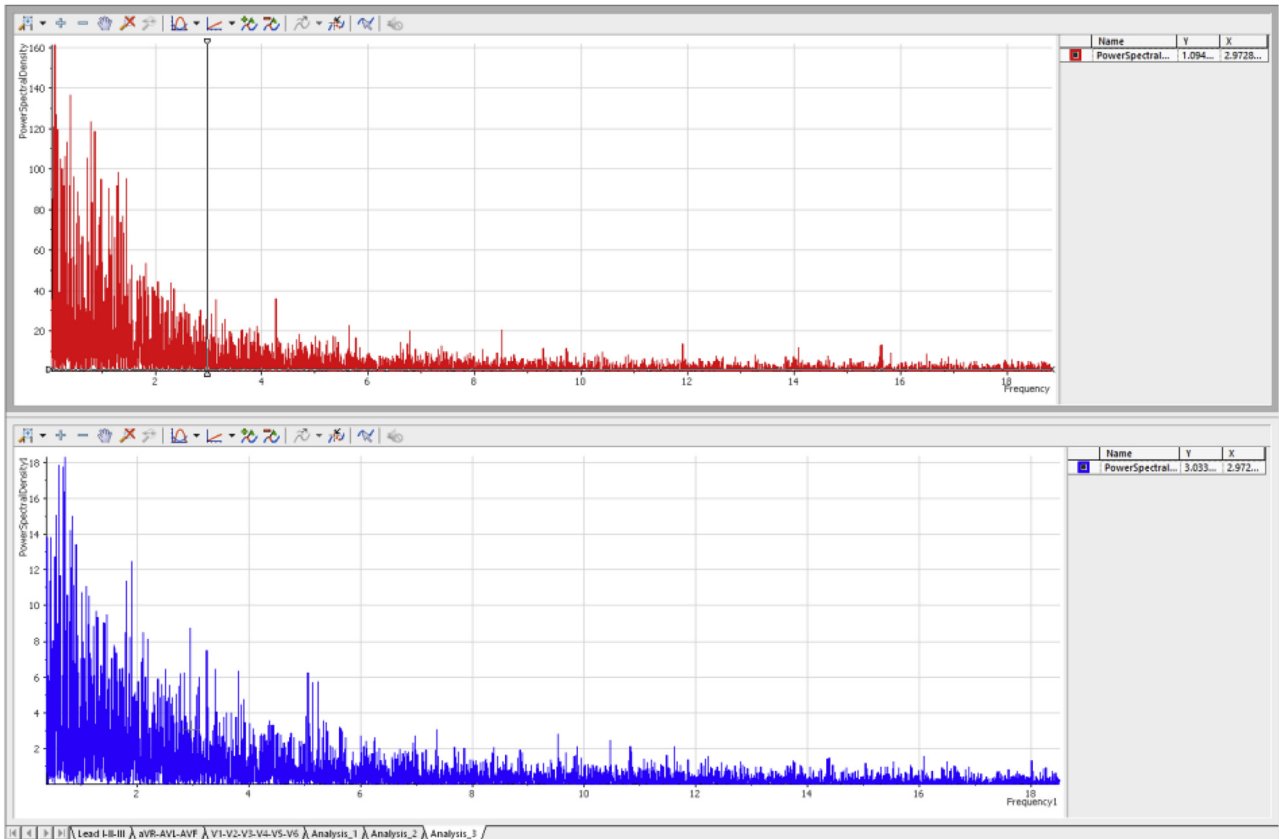


Fig. 11. EEG waves displayed in the frequency range

However, there are variables that exist only in one or only in the other.

The user dialog box is responsible for the communication between the user and the program. You can specify the

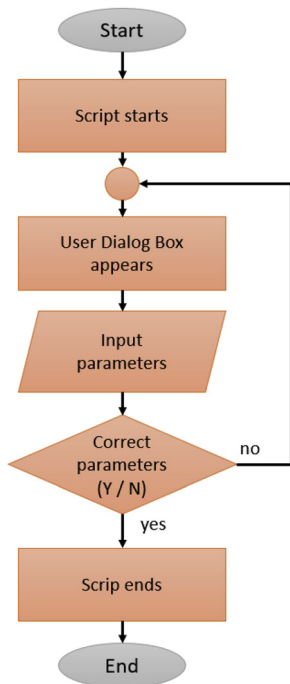


Fig. 12. The high-level flow chart

input parameters that will be used for the analysis. The surface can be divided into two parts. One element is the visual unit, which has blank fields, action buttons and radio buttons. The second element is the script itself, which communicates between these elements and the main program.

The visual interface of the User Dialog Box is shown in Fig. 13. We have the opportunity to input our name, date of birth and gender. In addition, you can choose between different lifestyle habits. You can select channels to analyse and enter parameters for the analysis. Such parameters are the number of groups displayed on the histogram or the minimum and maximum accepted heart rate.

The program runs with an error if the input parameters are incorrect and then repeats the program until the user enters the correct data. The program code considers values between 1900 and 2020 as acceptable categories at the year of birth. These limits are freely adjustable. If the specified year of birth is outside of the accepted values, it will be treated as an error.

The lines in the main program unit are responsible for processing, organizing, analysing and reporting the data. The program first loads the data from a predefined root folder. Then you need to specify the location of the data to be scanned, and the name and extension of the data. It is advisable to delete the data before each run to avoid misleading and unintentional adding of data packets.



Fig. 13. The visual interface of the User Dialog Box

The program then displays the User Dialog Box and executes the corresponding script. Based on the input parameters specified in the user interface, the previously executed analyses are executed during the execution of the script.

The script automatically detects the vertices of the raw data, creates a spline for the wave that can be fitted to the R-R vertices, and analyses them using a histogram. In histogram analysis, you can specify how many groups you want to form. This can be specified by the user in the User Dialog Box as an input parameter. The recommended value is 40, but the user is free to change it.

11. AUTOMATED REPORTING AND DATA EVALUATION

To make it easier to evaluate and document the data, the script automatically loads the predefined report templates and fills them with processed and analysed data. In addition, certain input parameters are also shown. The script creates 6 separate pages that display different types and amounts of data. On these pages, the date, time, page number, and the name of the project file are displayed in a given position. The number of pages can be further expanded, and the raw report files can be used in other scripts. The object-oriented

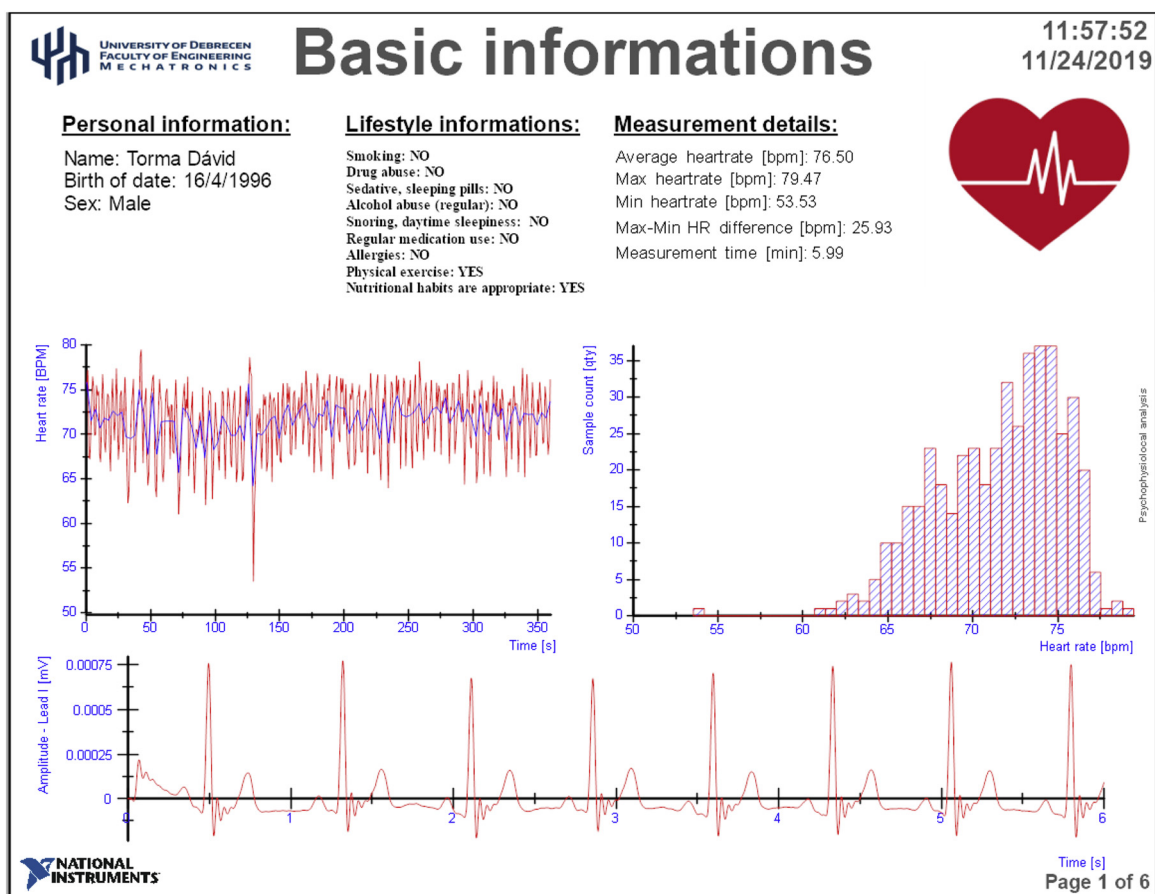


Fig. 14. The first page of the report

feature makes Visual Basic scripts recommended and beneficial.

The first page displays general information. This page is shown in Fig. 14. The second page analyses and detects normal sinus rhythm. The third surface of the prepared report shows the analysis of sinus bradycardia and sinus tachycardia and the symptoms of these diseases. The analysed values of the raw EEG data can be seen on the fourth page. The fifth page of the report shows the 12 leads used in the ECG measurement. The sixth and final page of the report displays temperature data.

12. DEVELOPMENT OPPORTUNITIES

The program created by the group can be used in several fields of life. The most important purpose is help the work of doctors and scientists. The program can analyse data in a monotonous and repetitive way, thanks to the script, which can be automatically evaluated. The human error factor can be eliminated because the program works in a predefined way. It is possible to add input parameters, thus simplifying administration tasks. Program development opportunities are expanding the amount of data used and analysis methods. With implementing a more complex analysis on both ECG and EEG data, a more comprehensive analysis can be obtained about the condition of the patient examined. Detecting and correcting potential code errors is also one of the development options. Collecting user feedback and fixing the most critical issues and bugs is also in progress. The program can analyse additional conditions but their calculation method will not be published.

13. SUMMARY

Our software is capable to automatically import data files, create display surfaces and fill them up with data. Analyse raw data and generate reports in a predefined way. The display interfaces allow data to be played synchronously. Using the built-in complex analysis features, the raw data can be properly processed and evaluated. These analyses are performed using user-defined input parameters. The program can identify certain disease symptoms and report them in report files. The program makes a significant contribution to effective work, making it easier for doctors, engineers and scientists to process data automatically, rather than repetitively and manually.

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