Diagnosis of Obesity with Bioimpedance Method

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Abstract. The article describes the bioimpedance method of obesity diagnosis. Such experiments are very important nowadays, because many people are obese and have problems connected with it. It is essential to check parameters such as a total body water (TBW), fat-free body mass (FFM), fat mass and body fat percentage in order to start a proper treatment and compose a right diet for the patient. Due to that fact, a special meter was constructed. The main aim of the project was to create a cheap, intuitive to operate, easily accessible equipment with high measuring credibility. The projected meter uses laptops and a LabVIEW application dedicated to measurements of bioelectrical impedance. Some results of the meter tests are shown in the article.

Keywords: bioimpedance, dietetics, obesity diagnosis, virtual instrument, LabVIEW.

1 Introduction

Because of the trends which are popular nowadays: a fast lifestyle and carelessness in selecting food, more and more people have problems with being overweight. Therefore, people go to dietetics so that they help them compose a proper diet that will allow them to maintain a slim figure. For this purpose it is necessary to determine the composition of the patient's body by performing non-invasive, yet effective electrical bioimpedance analysis (BIA)[1].

1.1 Problem of Obesity

The obesity is a serious problem with excessive accumulation of body fat. The obesity is diagnosed when the body fat exceeds the physiological needs of organisms. A woman is considered to be obedient when her body fat is higher than 25% of a total body weight and in case of men it is 20%. The thing that matters in not only its amount but also location.

The obesity is a heterogeneous group of conditions with multiple causes. It is determined by an interaction between a variety of factors:

- environmental the westernization of diet and lifestyles,

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- genetic - genetic diseases associated with mutations in genes,
- pharmacological some drugs can cause weight gain, eg. antidepressants and anxiolytics,
- biological caused by autonomic nervous system disorders, eg. damage of the hypothalamus (inflammation or cancer) and ventrolateral nucleus of the medial hypothalamus,
- psychological people who suffers depression often eat more which causes overweight [2].

The main reason is eating too much energetic food and a lack of the physical activity. Thus, it is strongly connected to the problem of overweight.

The obesity causes a variety of health problems. In particular, it is associated with the development of obstructive sleep apnoea, type 2 diabetes mellitus, heart disease, etc. A large obesity leads to disability. Obesity is a social issue in developed countries and in the future there may be an epidemic. It is considered to be one of the hazards of developed societies civilization. Therefore, it is necessary to diagnose this problem early and take action to cure the patient. In order to determine body fat (body composition) and diagnose the obesity, usually BIA measurement is performed or body mass index (BMI) is calculated. The latter is easier and does not require any special device, but the obtained result is approximate and has low reliability of measurement [3].

1.2 Bioimpedance

The bioelectrical bioimpedance is resultant total electrical resistance of tissues. It is the ratio of the applied voltage U to the AC current I flowing through the tissues. It consists of resistance R and reactance X, which is capacitance C in humans.

$$Z(\omega) = \frac{U(\omega)}{I(\omega)} = R + jX(\omega) = R - j\frac{1}{\omega * C} \quad (1)$$

The human bioimpedance is a very important diagnostic parameter. Its value depends on the humans body composition. The electrical properties of the issues changes with the properties of every structural part, eg. intracellular and extracellular substance, cell membrane and all organelles. Resistance depends on electrolyte concentration while capacitance depends on potential differences on cell membranes and varies with the current frequency which was used in examination [4][5]. If DC or low frequency is used, current cannot go through a membrane cell. The membrane behaves like an isolator and the extracellular route is pure resistance. On the other hand, if high frequency is used, a membrane cell behaves like a capacitor, so capacitance becomes associated with it [6].

In connection with the human tissues structure, the human body can be modeled as an electrical circuit which consists of two parallel branches: one branch with resistor and the other with resistor and capacitor connected in series [7]. It is why the body composition (especially water weight and fat mass) can be examined with bioimpedance method.

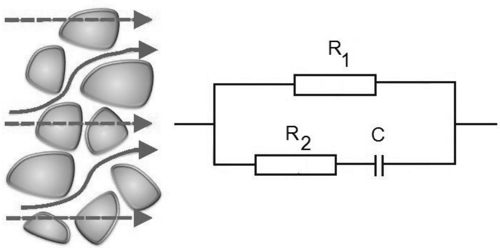

Fig. 1. The low frequency current (represented with a continuous arrow) flow extracellular and the high frequency current (represented with a dotted arrow) flow intracellular which is the reason that the human body can be modeled as resistance and capacitance connected in parallel[6][8].

2 Related Works

Two basic method of bioelectrical impedance analysis and dedicated BIA devices can be distinguished. Single Frequency Bioelectrical Impedance Analysis (SF-BIA) uses only one frequency (usually it is 50 kHz) and current 0,8-1 mA. It is applied to assessment of body composition in healthy subjects [1]. The very precise measurements of patients in postoperative period is performed by Multi Frequancy Bioelectrical Impedance Analysis (MF-BIA) method. A variety of signal frequencies is used: the range is 0-500 kHz (mostly 0, 1, 5, 50, 100, 200 or 500 kHz, but at frequencies below 5 kHz and above 200 kHz poor reproducibility has been noted [7].

There are four standard methods of bioimpedance measurements. Two of them use current source and two use voltage source. The other classification criterion is a number of sensors placed on the patient body. The bipolar methods use only two sensors (eg. hand-to-hand, hand-to-foot or foot-to-foot) while tetrapolar methods use four sensors (hand-to-hand-to-foot-to-foot) [4].

For dietetics diagnosis purpose there is commonly used a single frequency measurement of the whole body with tetrapolar system [1]. Unfortunately, the bioimpedance meters are very expensive so the cost of examination is also quite big and not everybody can afford it.

3 Projected Bioimpedance Meter

The aim of the meter project was to construct a cheap, intuitive and easily accessible equipment with high measuring credibility. Therefore the authors of the paper oryginally invented and constructed a system for bioimpedance measurements using widely accessible laptops, simple electronic circuits and intuitive software (an application in LabVIEW) [10].

Every medical equipment has to be safe for a patient as well as for a physician, so a galvanic separation is needed. Using a laptop running on battery power do not require any additional protection. There is a logical barrier and the battery is loaded only when the equipment is shut down. Two basic functional blocks of the bioimpedance meter can be distinguished:

– hardware (laptop with external sound card, signal adaptor - voltage divider and electrodes),
– software (the application dedicated to measurements of bioelectrical impedance which was developed in LabVIEW).

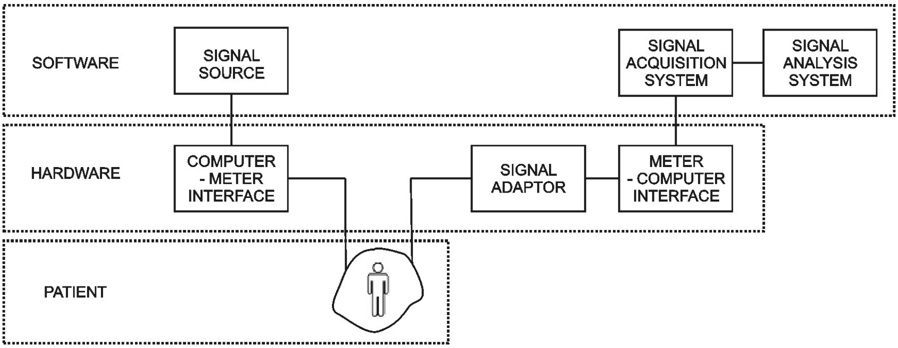

Fig. 2. Block diagram of the projected bioimpedance meter [10]

The above mentioned components are described with details in next subsections.

3.1 Hardware

The meter was created using the bipolar voltage method. In order to decrease cost of the construction, it was decided to use standard inputs and outputs available in every laptop: MIC IN and PHONES OUT. They were examined using HUNG CHANG 5804 40MHz oscilloscope and HAMEG HM8131-2 15MHz generator. Because of their nonlinear amplitude-frequency characteristic, it would be necessary to implement some extra complicated calibration functions in the software. Therefore, external sound card Behringer UCA202 was examined and used (it is not expensive and its inputs/outputs). Unfortunately each laptop has different internal parameters which cause that different signal amplification values are obtained [10]. To minimize artefacts caused by various computer architecture, calibration and parameterization of software have to be performed every time the device is connected to a new laptop for the first time. However, using LINE IN input and LINE OUT output does not require any additional signal preprocessing in software, because these outputs and inputs are linear.

The use of LINE IN and LINE OUT introduced restrictions in generated signal frequency. The minimal signal frequency value which will not be filtered is 100 Hz and the maximum one is 10 kHz regarding to the Nyquist-Shannon sampling theorem (sampling frequency of A/C and C/A converters in sound card is 22

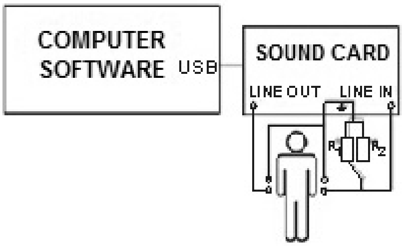

Fig. 3. The projected bioimpedance meter consists of a laptop connected to an external sound card with LINE OUT output and LINE IN input.[10].

kHz). There are also imposed limits of the input signal magnitude which value depends on the laptops type.

A voltage signal is generated and the voltage signal has to be acquired because of the output/input character. Regarding to the figure 2, it was necessary to create an electronic module which will be a kind of diagnostic signal adaptor a voltage divider with an additional resistor. Thus, the voltage value of the LINE IN signal is proportional to the resistance value and the current value which flows through this resistor (it depends on the measured bioimpedance). Such solution enables computing the current value as a ratio of the additional resistors value and the measured voltage value.

The big problem in medical diagnostics and biomedical equipment is caused by noise. It is essential to provide proper equipments and cables shielding and to use good quality sensors. In this case, there were used shielded cables from electrocardiography device and Ag/AgCl single-use electrodes.

3.2 LabVIEW Application

Control and measurement systems developed in LabVIEW are commonly used in engineering. This design platform and development system for a visual programming from National Instruments enables developing applications virtual instruments. When you use them, they are similar to real equipment [11][12]. That is the reason why LabVIEW was chosen to develop an application for bioimpedance measurements.

The author of this paper created the application dedicated to measurements of bioelectrical impedance. The application generates, acquires, processes and analyses the diagnostic signal in bioimpedance measurements.

The main programme is based on the Multiple Loop Architecture using Functional Global Variable.. It enables correct data flow control between programme elements which work in parallel. Three loops have to be performed at the same time:

- Event Handler Loop,
- Generation Loop,
- Acquisition and Analysis Loop.

The Event Handler loop was created using event structure. It defines an event (a code fragment [12]) which should be performed if one of the buttons on the user interface (Start, Pause or Stop) is pushed.

The information which event should be performed and the diagnostic signal data are stored and sent between the loops by specially created global variable. It consists of a data cluster including data which is essential to handling Generation Loop and Acquisition and Analysis Loop. Moreover, there are contained parameters of the generated and aquired signals. Values of the generated signal are to be found there too.

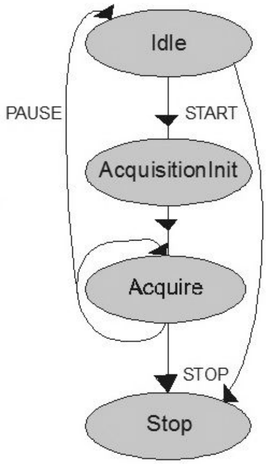

Fig. 4. State diagram of Case Structure in Acquisition and Analysis Loop presents the way how the states can change. The AcquisitionInit state initalizes the whole process, which is performed during Acquire state.

The Generation Loop and The Acquisition and Analysis Loop were created using an architecture which is similar to a state machine architecture as it uses a Case Structure. The difference is in a way of sending information by enum type control between each circuits [11][12]. Instead of a Shift Register, the aforementioned functional global variable was used. Both loops have an idle, initialization, the basic operation and stop states. The basic operation in Generation Loop is to generate a sinusoidal signal with set frequency and magnitude and then to put it in on the computer sound card outputs: PHONES OUT or LINE OUT. The Acquisition and Analysis Loop enables a signal acquisition from the computer sound card inputs: MIC IN or LINE IN, and then its analysis using an implemented algorithm. The acquisition and the analysis parts are combined together. It is caused by laptops memory and calculation capabilities [10]. If these two functions were to be separated, noticeable changes in the program structure would be needed and hardware requirements would increase.

The crucial element of the signal processing block in the application is a calcutation of an instantaneous bioimpedance value. It enables creating a plot of how bioimpedance varies in time (an impedance curve). Moreover, the obtained data is analysed in terms of fat content in the body. The algorithms were implemented to calculate some diagnostic parameters: total body water (TBW), fat-free body mass (FFM), fat mass and body fat percentage [1].

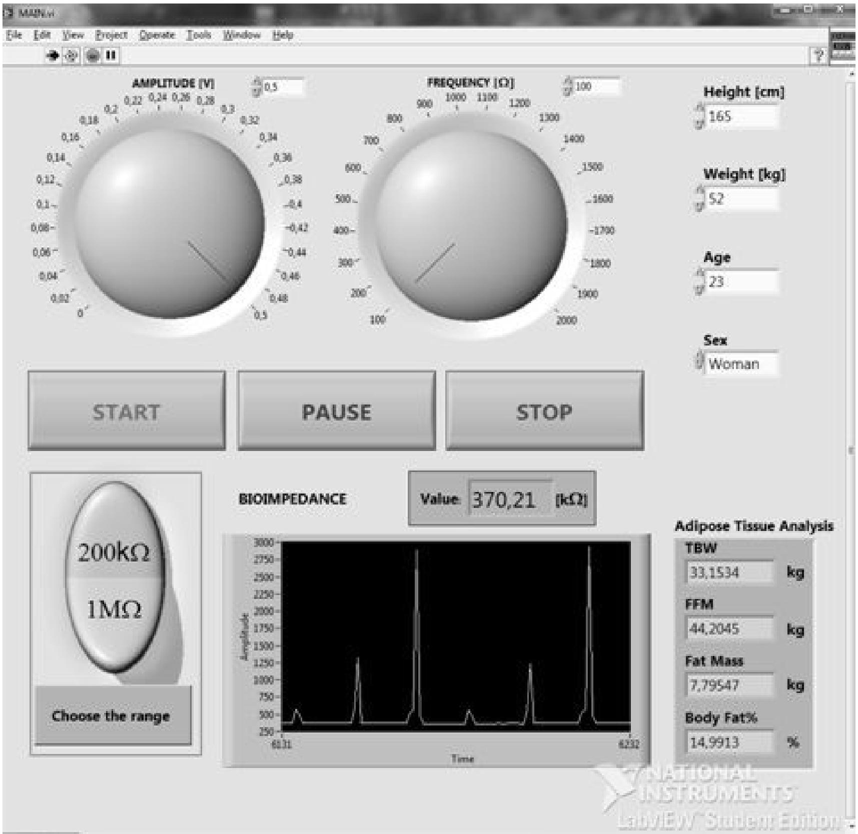

Fig. 5. User interface of the application dedicated to the bioimpedance measurements [10]

The specialized software was prepared in LabVIEW 2011 Student Edition and then compiled in LabVIEW 2010 Professional Development System. The installation file with LabVIEW Run-Time Engine was prepared so that the installation is simple and quick, application costs are low and less computer memory is needed [11].

4 Results

Some tests of the configured device were made. Due to the fact that every laptop has different internal parameters, it was necessary to calibrate the meter every time when a laptop was used for a very first time. Firstly, the meter was examined using reference decade resistance. The measurement error was lower than 2% and it is an acceptable result. No matter what signal frequency was used, the results were the same. It is because the pure resistance does not depend on the frequency.

Table 1. Results of the device test using decade resistors and laptop Lenovo 3000 N20

Real set resistance [kΩ], the device class: 0,05	The resistance value measured by the virtual instrument [kΩ]	Relative error of the meter [in %]
10	9,90	1,00
50	50,81	1,62
100	101,9	1,90
150	152,27	1,51
200	204,57	1,29
250	254,15	1,66
300	299,85	0,05

Moreover, the device was tested on 23-year-old woman using electrodes attached to the top of her hands. For example, for signal with amplitude peak-to-peak 1,5V and frequency 500 Hz the bioimpedance was equal to 332 kΩ (TBW=36,30 kg, FFM=49,71 kg, Fat Mass=2,27 kg, Body Fat=4,37%) and for signal with frequency 10 kHz the bioimpedance was equal to 315 kΩ (TBW=37,95 kg, FFM=51,98 kg, Fat Mass=0,02 kg, Body Fat=0,03%). The difference between these two results is seen if view of the fact that when the signal frequency is higher, the capacitance component appears.

5 Conclusion

In the paper the bioimpedance meter designed to the obesity diagnosis was described. Regarding to the obtained results, it turned out that it is technically and economically possible to construct bioimpedance device using special software in LabVIEW and hardware including laptops and sound cards. It is planned to configure the device with a tablet or a smartphone instead of a laptop. Some changes in the application will also be made. The possibility to connect to the patients database and save the measurements results will be introduce. It will facilitate the physicians work.

There is an issue is with the frequency limits imposed by the sound card input and output. Usually, as it was show in section 2, bioimpedance measurements in dietetics are performed using high frequency signal, but in this solution it was impossible. The device can generate only some of the frequencies used in MF-BIA: 0, 1, 5 and 10 kHz. Due to this fact, the created device can be used in diagnosis of obesity only in a limited way.

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