

LEARNING SYSTEM OF THE ECG FUNDAMENTALS

SISTEMA DE APRENDIZAJE DE LOS FUNDAMENTOS DE ECG

Gabriela Téllez Pedraza

Universidad de Celaya, México
15015106@udec.edu.mx

Vianey Gasca Amézquita

Universidad de Celaya, México
18013079@udec.edu.mx

Hilda Mayela Aran Adriano

Universidad de Celaya, México
17015263@udec.edu.mx

Eli Marcela Vega López

Universidad de Celaya, México
16010754@udec.edu.mx

Alonso Alejandro Jiménez Garibay

Tecnológico Nacional de México / IT de Celaya
alonso.jimenez@itcelaya.edu.mx

Reception: 16/may/2020

Acceptance: 10/november/2020

Abstract

The present work is oriented to the development and design of a system that allows to simplify the learning of the fundamentals of electrocardiography. The proposed system uses NI LabVIEW software and the Biomedical Toolkit to design an interface with graphic and descriptive elements of a cardiac biopotential that generates normal heartbeats and / or abnormalities in the heartbeat. The result is an alternative tool in the teaching-learning process for medical, biomedical or bioengineering students.

Keywords: Learning System, ECG, NI LabVIEW.

Resumen

El presente trabajo está orientado al desarrollo y diseño de un sistema que permita simplificar el aprendizaje de los fundamentos de electrocardiografía. El sistema propuesto utiliza el software NI LabVIEW y el Toolkit de Biomédica para

diseñar una interfaz con elementos gráficos y descriptivos de un biopotencial cardíaco que genere latidos cardíacos normales y/o anomalías en el latido cardíaco. El resultado es una herramienta alternativa en el proceso de enseñanza-aprendizaje para estudiantes de medicina, biomédica o bioingenierías.

Palabras Clave: Sistema de Aprendizaje, ECG, NI LabVIEW.

1. Introduction

Impedance cardiography is a non-invasive, safe and affordable method of monitoring stroke volume and cardiac activities. Since impedance cardiography has the potential to supply cardiovascular variables on a beat-to-beat basis, it allows us to monitor systolic time intervals, stroke volume and systemic vascular resistance along with having the perks of being a non-invasive method that is able to check blood pressure. Hence, a technique of this level of sophistication and accuracy would be very valuable in patients with acute myocardial injury and other conditions.

Impedance cardiography is centered on Ohm's Law ($V = RI$), where R is resistance (measured in Ohms), V is voltage (measured in Volts) and I is current (measured in Amps).

Our body presents certain opposition against electric signals just like any circuit. But this resistance that the body produces is known as impedance (Z) and can also be determined as $Z = V/I$ in an impedance cardiography. This Law is translated to a model designed for the human body, which is the parallel conductor model. Said model presumes that the impedance of thoracic tissue is parallel to that of blood [Woltjer, 1997].

A cardiography consists in using four electrodes and putting them around the heart in different positions to catch and register the impedance and cardiac performance. However, the way one places the electrodes on the patient's body plays an important part in the accuracy of the cardiac measurements and changes in impedance [Shookin, 1997].

The process consists in putting two electrodes on the neck and two on the thoracic region, to create a high frequency, low amplitude electrical current and to obtain an impedance difference signal from the electrodes located in the center. These

electrodes cause a high frequency fluctuating current to the patient while the second pair of electrodes sense the voltage levels that the patient's heart has.

The impedance of the patient at each of the inner pair of electrodes could be calculated from the previously obtained voltages and established currents [Wang, 1992]. Then, one must correlate the changes in electrical impedance with cardiac parameters to obtain a clear result.

However, a cardiography will usually come in hand with an electrocardiogram (ECG) to observe the signals that the heart produces but in order to read such signals, one must filter and get rid of the noise or alterations that may manipulate the signal we are looking for. In cases like these, efficient signal processing is crucial to ensure accuracy in a cardiography.

A cardiography is a sophisticated process that also requires a computer system to analyze the impedance signal in different ways to deliver an accurate report of cardiac parameters. The computer system transmits a sinusoidal test curve to the transducer receiver and then measures and records the gain-phase-frequency distortions created by the receiver. The "real" impedance signals received by the computer system through that transducer are filtered to remove the distortions that it may carry, ensuring a correct and efficient reading.

ECG-focused learning systems have been used for different purposes, [Zhang, 2013] conducted a quasi-experimental study with conference methods and self-study manuals for nurses working in the emergency department, obtaining effective results improving their knowledge.

Just as in nurses these techniques have been implemented in students, [Muller, 2005] implemented antiarrhythmic therapy and the ECG in Simulator-based medical education in third-year students in the Dresden School of Medicine Program underwent a 6-week course "Basics of Drug Therapy", demonstrating an effective tool for teaching clinical pharmacology.

The interpretation of ECG and management of cardiac arrhythmia are based on conferences not adapted to the student's commitment, [McClauley, 2017] created a mobile device interface in an adaptive and spaced format, this plan allowed to improve the mastery of the interpretation and management of arrhythmia.

Such as these methods, in the UK court, a workshop test for medical students was carried out [Baral, 2020] led the workshop consisting of different pathologies related to cardiac disorders, after this workshop an evaluation was done emphasizing activity-based learning, justifying further exploration with multi-center controlled studies involving students improving the competence of health professionals to interpret ECGs.

According to [Breen, 2019] the correct interpretation of the 12-lead ECG recordings is complex and clinically challenging, since a wrong interpretation has the potential to give poor results or even patient death. The literature suggests that up to 33% of ECG interpretations have some error compared to the expert reference and up to 11% resulted in inappropriate handling. The ubiquity of the ECG in clinical practice and the over-reliance on computer-assisted interpretation of the ECG are also explored as factors affecting clinical skill acquisition and retention.

Cardiac abnormality detection and localization systems are currently being developed for hospitals such as for learning. [Liu, 2020] developed a system for locating myocardial infarction in based on a non-invasive ECG, using a noise elimination algorithm offering an improvement in automated detection and clinical practice.

The role of the ECG is fundamental in the medical field for the analysis of cardiac physiology, according to filtering analysis by [Appathuari, 2019] develop novel algorithms, segmentation and ECG classification, for academic and medical use, using different programs, in this case Matlab.

It is important to reinforce learning techniques within the health area, a study by [Novotny 2015] indicates that between 5 and 6% of diagnoses made by fellows and medical students are dangerously incorrect, which indicates a risk for patients, showing that educational means must improve so that this percentage decreases.

Progress to improve learning is growing very fast, [Anas, 2014] developed a bioelectric selak measurement algorithm, improving the interpretation of parameters under certain conditions, helping to monitor and analyze in real time.

This paper describes the methodology and results of a learning system to know the fundamentals of ECG interpretation. The main innovation is based on the use of NI

LabVIEW software and the biomedical toolkit. In contrast to published work cited previously, the proposed ECG, gives a theoretical overview of the waveform, this represent a very useful to the student. Besides, it is not an acquisition system, so it does not require the patient. It also offers the user the possibility to build the desired ECG waveform.

2. Methodology

The methodology relies on the analysis of Biomedical Engineering subjects, such as medical instrumentation I and II, physiology, and anatomy. Supported by medical advice, the main idea is based on the design of a learning system that allows the student to have a general overview, related to the interpretation of ECG.

The proposed learning system is programmed in NI LabVIEW, thanks to the versatility that this software presents in the interface design. Also, it is complemented by the Biomedical Toolkit. The NI LabVIEW Biomedical Toolkit is a collection of ready-to-run applications, utilities, and algorithms designed to simplify the use of NI LabVIEW software in physiological DAQ, signal processing, and image processing. The Toolkit includes applications commonly used in teaching physiology, bioinstrumentation, and biomedical signal processing and provides researchers with tools to create powerful custom applications to accelerate their research. Ready-to-run applications include the Biosignal Datalogger and Player, File Viewer, Biosignal Generator, ECG Feature Extractor, Heart Rate Variability Analyzer, Non-invasive Blood Pressure Analyzer, 3D Image Reconstructor, and File Format Converter. The file conversion utility imports many common biomedical data logger formats into the NI Technical Data Management Streaming format including Biopac. ACQ, iWork, MAT, EDF, and HL7. [Sidkova, 2019] figure 1 shows the toolkit functions that include signal processing algorithms for common processing tasks on many biosignals such as EEG and ECG signal simulation, EEG bispectral and coherence analysis, ECG feature extraction, and EMG power analysis.

Following medical recommendations, from the subject's professors. To have an overview of what an ECG represents and how it can help students in the classroom, the learning system should contain the following ECG concepts, shown in figure 2.

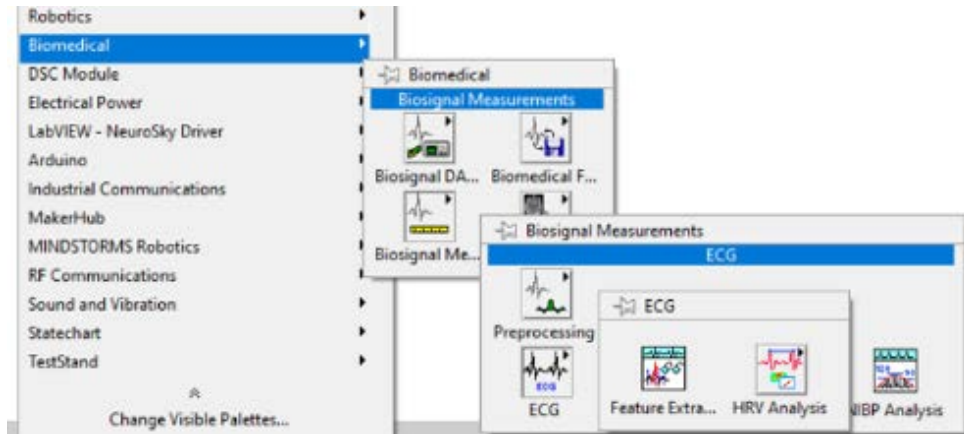


Figure 1 NI LabVIEW Biomedical Toolkit.

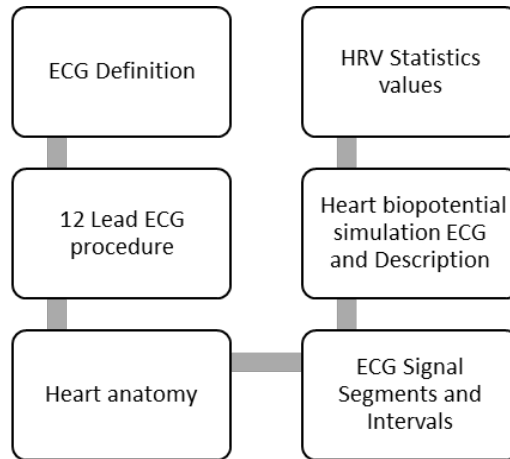


Figure 2 ECG Learning System – Interface Content.

3. Results

The design of the virtual instrument (VI) in the NI LabVIEW software complies with the recommended contents in the methodology section. In addition, the system is capable of generating different scenarios of cardiac abnormalities, such as:

- atrial tachycardia
- ventricular tachycardia
- junctional tachycardia
- hyperkalemia
- hypokalemia
- hypercalcemia

All of them with setup possibilities, for example, contamination by artifact noise, variability of limits in amplitude, etc.

The definition of an ECG, is the first component of the learning system. Electrocardiography (ECG) is a fast, simple, and painless method in which the electrical impulses of the heart are amplified and recorded. This log provides information about the location of the heart that triggers each beat (the sinus node, also called the sinoatrial node), the nerve pathways that drive cardiac stimuli, and the rate and rhythm of the heart.

The 12-Lead ECG electrode placement, is the second component of the learning system, this procedure paints a complete picture of the heart's electrical activity by recording information through 12 different perspectives. Think of it as 12 different points of view of an object woven together to create a cohesive story - the ECG interpretation.

These 12 views are collected by placing electrodes or small, sticky patches on the chest (precordial), wrists, and ankles. These electrodes are connected to a machine that registers the heart's electrical activity, as shown in the figure 3.

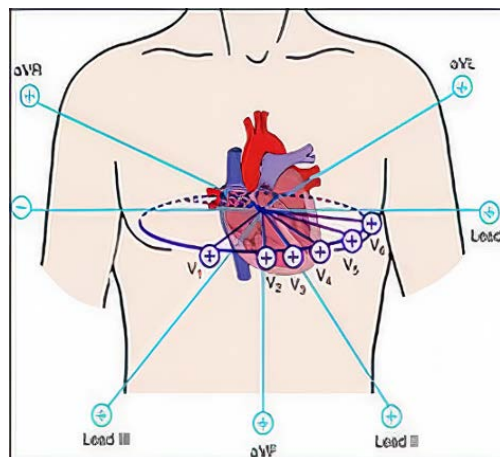


Figure 3 12-Lead ECG electrode placement.

The third component shows the principal parts of human heart anatomy, as seen in figure 4. The fourth component is related to the ECG intervals and segments. The VI uses an illustrated waveform with intervals and segments. Accompanied by the corresponding definitions, as seen in figure 5.

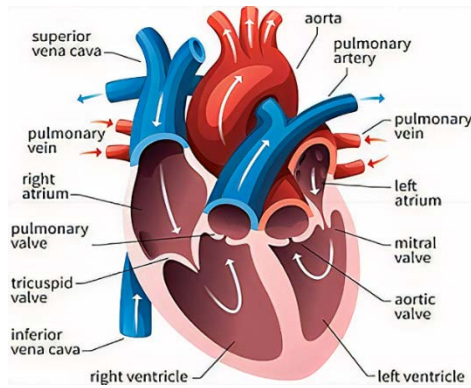


Figure 4 Parts of the human heart anatomy.

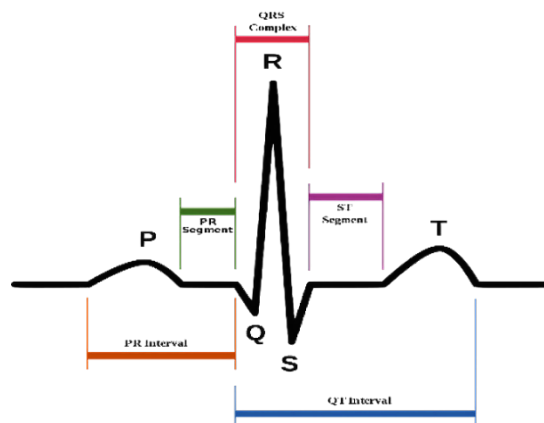


Figure 5 Segments and intervals of a normal ECG.

Intervals and segment definitions.

- PR Interval: From the start of the P wave to the start of the QRS complex
- PR Segment: From the end of the P wave to the start of the QRS complex
- J Point: The junction between the QRS complex and the ST segment
- QT Interval: From the start of the QRS complex to the end of the T wave
- QRS Interval: From the start to the end of the QRS complex
- ST Segment: From the end of the QRS complex (J point) to the start of the T wave

The fifth component of the VI presents the main innovation of the learning system and is related to the ECG simulation and description. As mentioned in the first part

of the results section, this VI is capable of generating different scenarios of cardiac abnormalities.

For a normal ECG scenario, the figure shows the learning system final appearance. The figures 6, 7 and 8, presents the abnormality cardiac scenarios for atrial tachycardia and ventricular tachycardia. The other scenarios for junctional tachycardia, hyperkalemia, hypokalemia, and hypercalcemia are not presented within the VI due to space issues in the paper.

Lastly, the proposed learning system also shows the results of statistics of the heart rate variability (HRV), it is a fundamental element to know the cardiovascular health of athletes. The relationship with adaptation to certain training loads, as well as recovery, has already been demonstrated.

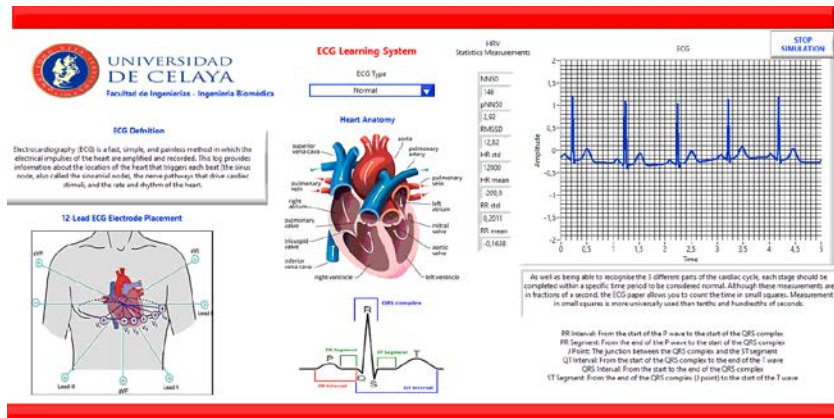


Figure 6 Front panel of a simulation of a normal ECG.

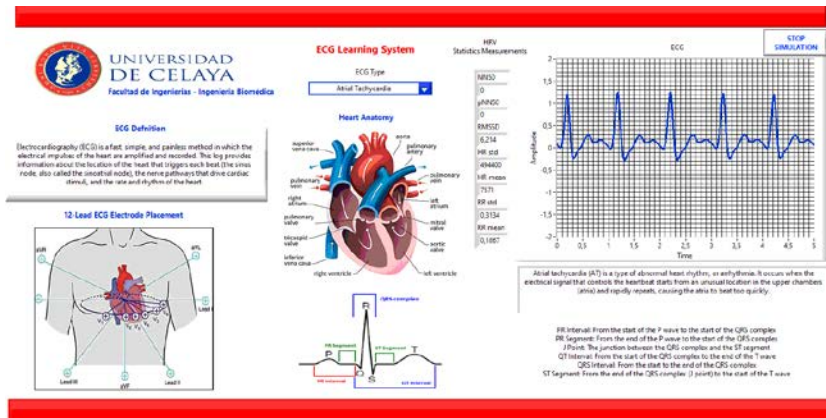


Figure 7 Front panel of a simulation of an atrial tachycardia ECG.

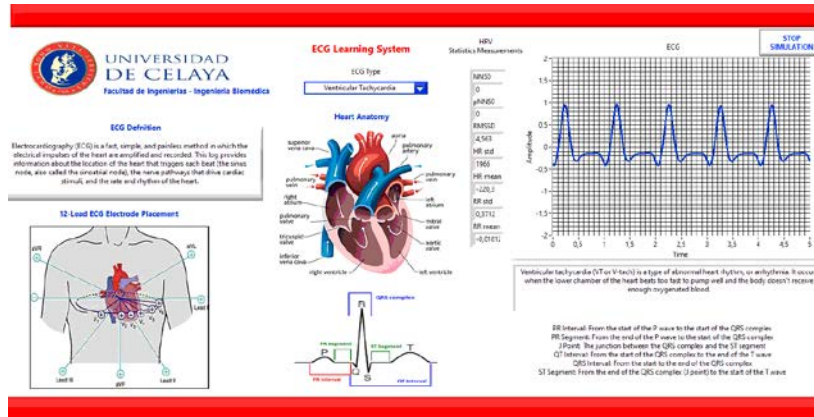


Figure 8 Front panel of a simulation of a ventricular tachycardia ECG.

Evaluated the relationship between heart rate variability (HRV) to determine different ventilatory thresholds.

4. Discussion

For decades, educational research oriented to different areas of engineering has published a wide variety of alternatives. The evaluation of them will depend largely on the use that is provided in the classroom. This paper is not intended to diagnose for any reason, its use is purely didactic for subjects that contain analysis of electrical biopotentials of the heart, such as in biomedical engineering.

5. Conclusions

This paper presents an alternative for learning the fundamentals of ECG. The design is oriented to the basic needs of the classroom, in useful concepts for the understanding of electrical biopotentials of the heart. The main innovation lies in the use of NI LabVIEW to create a user-friendly interface for the student or teacher plus the possibility of used the biomedical toolkit to design an ECG waveform generator, very useful in biomedical o mechatronics experiments, instead of a sensor-based acquisition system. As future work, the system will be validated by biomedical engineering students from the University of Celaya or engineering students interested in the subject of ECG. The information collected will allow statistical validation.

6. Bibliography and references

- [1] Woltjer H.H., Bogaard H.J., de Vries P.M., The technique of impedance cardiography, *European Heart Journal*, Volume 18, Issue 9, 1997.
- [2] Schookin, S. I., Zubenko, V. G., Beliaev, K. R., Morozov, A. A., & Yong, W. H. (1997). U.S. Patent No. 5,685,316. Washington, DC: U.S. Patent and Trademark Office.
- [3] Wang, X., & Sun, H. H. (1994). U.S. Patent No. 5,309,917. Washington, DC: U.S. Patent and Trademark Office.
- [4] Dayra, Como redactar y publicar artículos científicos. Organización Panamericana de Salud, 1994.
- [5] Zhang H., Lihwa L. (2013). The effectiveness of an education program on nurses' knowledge of electrocardiogram interpretation. *International Emergency Nursing*, 22, pp. 247-251.
- [6] Muller M., Christ T., Dobrev D., Nitsche I., Stehr S., Ravens U., Koch T., 2005 Teaching antiarrhythmic therapy and ECG in simulator-based interdisciplinary undergraduate medical education. *British Journal of Anaesthesia*, 95, pp. 300-304.
- [7] McClauley B., Chu A. (2017). Using mobile device technology and spaced education adaptive learning algorithms to teach ECG interpretation. *Journal of the American College of Cardiology*, 69, p. 2492.
- [8] Baral R., Declan C., Mahmood A., Vassilios S. (2020). The effectiveness of a nationwide interactive ECG teaching workshop for UK medical students. *Journal of Electrocardiology*, 58, pp. 74-79.
- [9] Breen c., Kelly G., Kernohan W., (2019). ECG interpretation skill acquisition: A review of learning, teaching and assessment. *Journal of Electrocardiology*, 39, pp. 30-35.
- [10] Sidkova M., Ladrova M., Martinek R., Kahanek M., Bilik P., Jaros R. (2019). Adaptive fetal ECG signal extraction based on LabVIEW and C# implementation. *IFAC- PapersOnLine*, 52, pp. 359-364.
- [11] Liu J., Zhang C., Ristaniem T., Parviainen T., Cong F. (2020). Automated detection and localization system of myocardial infarction in single-beat ECG

- using Dual-Q TQWT and wavelet packet tensor decomposition. *Computer Methods and Programs in Biomedicine*, 184, pp. 105-120.
- [12] Appathuari A., Jerusalin C., Kumar S., Ashy V., Ganana a., Lenin a., Krishnamoorthy S. (2019). A study on ECG signal characterization and practical implementation of some ECG characterization techniques. *Measurement*, 147, p. 384.
- [13] Novotny T, Bond R., Andrsova., Koc L., Sisakova M., Finaly D., Guldering D., Spinar J., Malik M. (2015). Data analysis of diagnostic accuracies in 12-lead electrocardiogram interpretation by junior medical fellows. *Journal of Electrocardiology*, 48, pp. 988-994.
- [14] Anas M., Norali A., Jun W. (2014). On-line Monitoring and Analysis of Bioelectrical Signals. *Procedia computer Science*, 42, pp.365-371.