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To cite this article: G Daniel *et al* 2007 *J. Phys.: Conf. Ser.* **90** 012013

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Real-time 3D vectorcardiography: an application for didactic use

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Abstract. The traditional approach to teach the physiological basis of electrocardiography, based only on textbooks, turns out to be insufficient or confusing for students of biomedical sciences. The addition of laboratory practice to the curriculum enables students to approach theoretical aspects from a hands-on experience, resulting in a more efficient and deeper knowledge of the phenomena of interest. Here, we present the development of a PC-based application meant to facilitate the understanding of cardiac bioelectrical phenomena by visualizing in real time the instantaneous 3D cardiac vector. The system uses 8 standard leads from a 12-channel electrocardiograph. The application interface has pedagogic objectives, and facilitates the observation of cardiac depolarization and repolarization and its temporal relationship with the ECG, making it simpler to interpret.

1. Introduction

The educational importance of laboratory experiments is unquestionable in biomedical sciences training, and those practices that involve measuring of in-vivo variables are particularly motivating for students. Among them, it is worth mentioning the recording of physiological variables in humans.

In undergraduate courses, cardiac electrical activity is typically introduced as a part of the studies on the electrocardiogram, after dealing with cellular electrophysiology. The origin of the ECG signal is a complex phenomenon, and its understanding is not always easy to grasp for students facing this topic for the first time.

Difficulties range from the recording technique itself to the interpretation of the normal or pathological electrocardiogram. They also include digressions between the cardiac dipole and the instantaneous cardiac vector, bipolar or unipolar leads, volume conductors, impedance, as well as issues related to noise, interferences and artifacts that can affect the recording.

In physiology courses of biomedical programs, it is common for the electrocardiography hands-on practice to be restricted to obtaining a scalar ECG recording, which is later analysed regardless of the concepts associated to the events occurring in it.

Pedagogic practice reveals that much more is learned by doing than by reading, and that spatial visualization of intrinsically three-dimensional phenomena allows for a better understanding than what is possible with bi-dimensional and uni-dimensional projections, as is the case of scalar ECG. Taking this into account, we developed a software application that facilitates understanding the cardiac bioelectrical phenomena by means of a real-time 3D visualization of the trajectory of the instantaneous cardiac vector, considering two bipolar leads (DI and DII), and the precordial leads V1 to V6 obtained through a 12-channel electrocardiograph.

2. Vectorcardiography

In the early 1960's, E. Frank developed a method of ECG electrodes placement with which he was able to obtain a 3D representation of the electrical activity through the conduction system of the heart, represented by right-left axis (X), head-to-feet axis (Y) and front-back (anteroposterior) axis (Z).

Frank's method directly generates orthogonal projections over the cardiac planes: frontal, horizontal and sagital. Each projection records simultaneously the same electric episodes on two perpendicular axes. The frontal plane records simultaneously the episodes on axes X and Y; the horizontal plane records simultaneous episodes on axes X and Z; and the sagital plane records simultaneous episodes on axes Y and Z.

To calculate Frank's leads X, Y and Z using the standard leads system, the following expressions are used:

$$X = -(-0.172 V1 - 0.074 V2 + 0.122 V3 + 0.231 V4 + 0.239 V5 + 0.194 V6 + 0.156 DI - 0.010 DII) \quad (1)$$

$$Y = (0.057 V1 - 0.019 V2 - 0.106 V3 - 0.022 V4 + 0.041 V5 + 0.048 V6 - 0.227 DI + 0.887 DII) \quad (2)$$

$$Z = -(-0.229 V1 - 0.310 V2 - 0.246 V3 - 0.063 V4 + 0.055 V5 + 0.108 V6 + 0.022 DI + 0.102 DII) \quad (3)$$

From these scalar coordinates, it is possible to obtain the instantaneous cardiac vector, whose path in space builds, beat after beat, the vectorcardiographic loops, the signal of interest for our study. [3], [6]

3. Materials and Methods

This application was developed using Borland C++ Builder 4, because its working environment is easy to use and provides visual objects built in routines for easy implementation of user interface features. Moreover, it is compatible with the OpenGL 3-D graphic library that allows optimizing the graphical and visualization processes. This is of great importance to create real-time graphic software.

Our application could be used, in general, with any 12-channel ECG machine with a real-time digital output. We used an ECGView digital electrocardiograph (Ekosur S.A., Buenos Aires, Argentina). This machine performs an analogical acquisition and an A/D conversion of the leads obtained from a 10-lead patient cable. The machine is connected to a USB port in a PC, from where all the acquisition process can be managed.

The device is controlled using a dynamic link library that allows starting and stopping communications and data acquisition. We made the validation tests of the obtained ECG recordings and, once data quality was checked, a VCG graphics stage and the rest of the application modules were developed.

4. Application Description

This software allows real-time 3D visualization of the instantaneous cardiac vector. The interface consists of a command window (main panel) and a graphics window, where the ECG traces and cardiac vector can be seen.

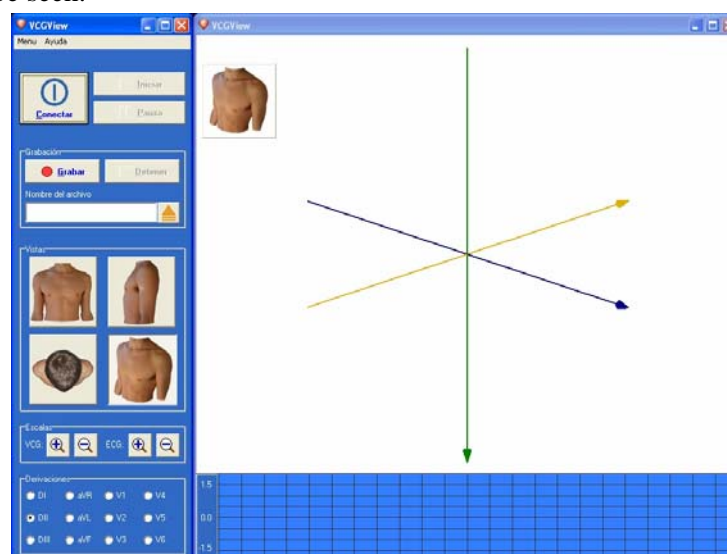


Figure 1: Application Main Panel

4.1. Main Panel

The main panel consists of the keys for connection with the acquisition system, the lead selector for the ECG graphics, the view and cardiac vector projection selector, a help menu and the data recording control buttons. Once the connection with the acquisition system is established, some control buttons become active.

4.2. Graphic's Window

It is divided in two parts: the upper part for the cardiac vector, and the lower part for the ECG traces. On the upper part, Frank's orthogonal axis are drawn (X, Y, Z in blue, green and orange respectively). In the lower part, a grid that simulates an electrocardiographic recording paper is shown, with the divisions expressed in mili-Volts on the ordinate axis, to measure the amplitude of the ECG signal.

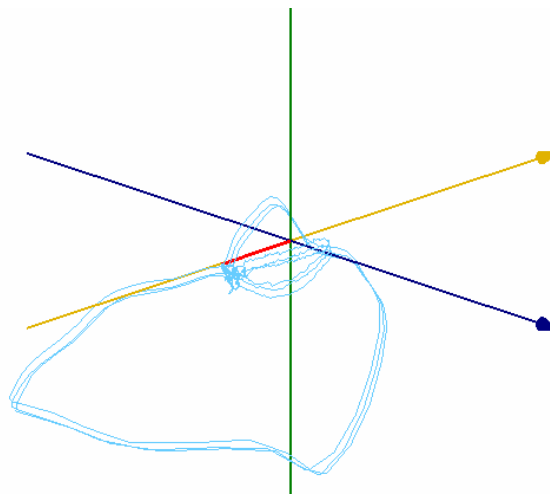


Figure 2: 3D View of instantaneous cardiac vector

4.3. Display Options

4.3.1. Leads

There is a key for lead visualization selection. The default is DII. Only one lead is seen at a time.



Figure 3: Lead visualization selector

4.3.2. Views

The software provides users with the most common projections of the cardiac vector: front view, left lateral view and top view. There is also a fourth view, the 3D one, which is the default setting. View is chosen from a button panel with graphic references to the available projections.



Figure 4: View Selector

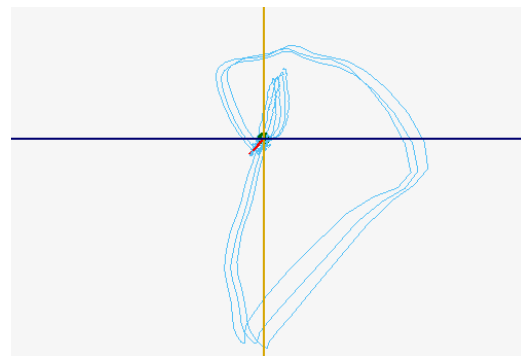


Figure 5: VCG top view example

4.3.3. Zoom

In case the graphics exceed the screen's limits, or when they are very small, they can be adapted for a better visualization with the scale buttons.

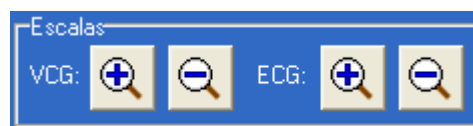


Figure 6: Zoom panel

4.4. Recording and playing

Another important feature provided by the application is the possibility of recording the measurements in a text file. The stored data consist of the main eight leads provided by the hardware (DI, DII, V1, V2, V3, V4, V5 and V6). These are organized in columns with the above-mentioned order.

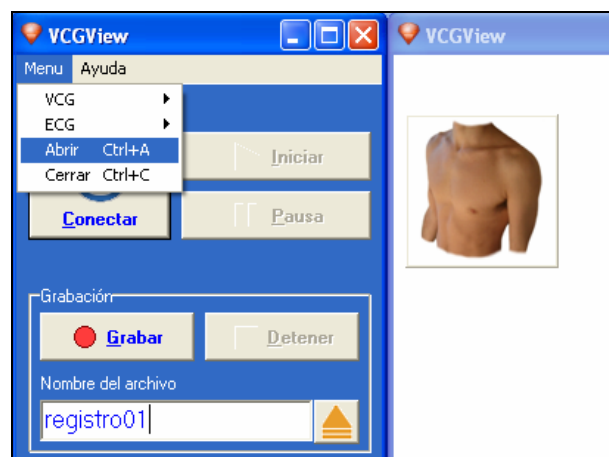


Figure 7: Recording and playing panel

The recording and stop keys are found in the central part of the main panel. The user can choose the path where the file will be stored.

Once the recording process is finished, the user can visualize the desired record, selecting a function button located on the top part of the panel menu.

4.5. Concepts Help Function

For those users novice to the study of vectorcardiography, a 'concepts assistance module' is provided, through which, step by step, all the physiological and biophysical phenomena related to the cardiac vector are described.

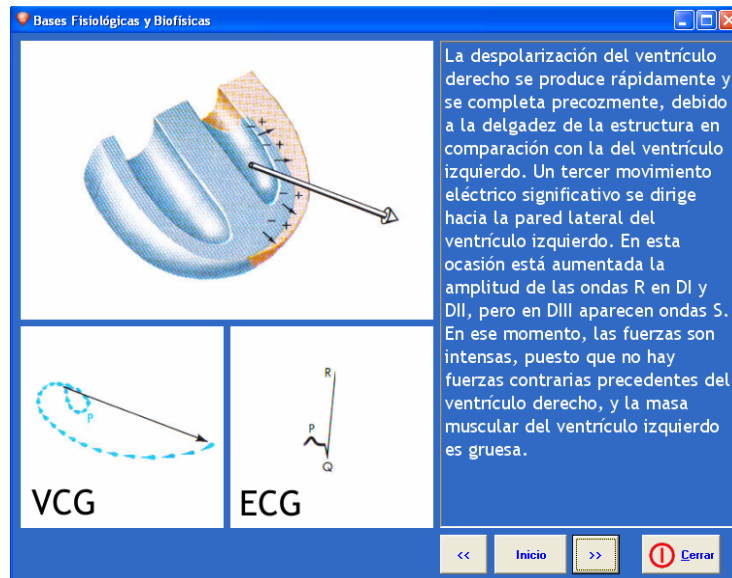


Figure 8: Concepts assistance module

In the left upper part of the window, the distribution of the heart's depolarized zones in each stage is represented, and in the bottom part, the corresponding VCG and ECG traces are displayed. On the right-hand side of the images, a text providing a brief explanation of the visualized signal is displayed. Therefore, after learning some key concepts on physiology and biophysics, the user can analyze and interpret those phenomena that happened in real-time.

5. Software applications

From among the ample number of didactic and clinical applications, some examples are shown:

5.1. Didactic applications [5],[6]

- Temporal correlation of VCG cardiac depolarization and repolarization loops with the ECG waves and segments.
- Spatial position of the heart within the thorax and the relative differences between patients of different gender, height and build.
- Influence of breathing on VCG and ECG recordings. The breathing effects are shown as a spatial displacement of the loop.
- Influence of the different types of noise on the loop and on ECG visualization. In the acquisition there might occur AC power line interference, muscular noise, artifacts and offsets due to the electrode-patient interface.
- To analyze the loop's projections on different planes and to understand the contribution of each ECG lead to the loop.
- To visualize the loop's spatial changes in the different anatomical positions which the patient might adopt.

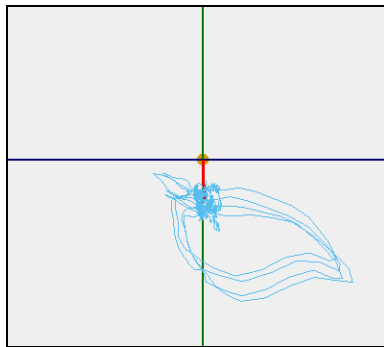


Figure 9: Breathing effects on VCG

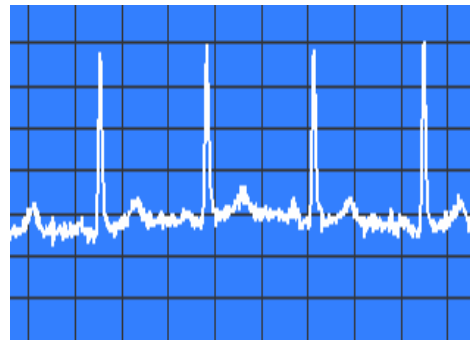


Figure 10: Muscular noise effects on ECG

5.2. Clinical Applications

- To supply a diagnosis or to try to prevent a severe acute myocardial infarction, by analyzing the heart's ischemia.
- To detect a relative atrophy condition, by analyzing the size of the surface that comprises the loop.
- Continuous monitoring during an angioplasty for early detection of coronary insufficiency [1].
- Postoperative monitoring of patient's evolution after an acute myocardial infarction.

6. Conclusions

Due to the difficulties in the comprehension of the key basic concepts of ECG and VCG, we developed a didactic application of 3D VCG. This application has shown to be of great utility in laboratory experiments. The students had the sense of being observing "from inside" the cardiac bioelectric phenomena, in contrast to the simple analysis of ECG records, with which the students consider themselves as "external" observers. The easiness of use along with the possibility of experimenting in real-time increases the didactic power of this tool, allowing for a variety of experiments that facilitate the learning of ECG fundamentals and its rational interpretation.

7. References

- [1] Andersen K, Eriksson P, Dellborg M. 2000 Ischaemia detected by continuous on-line vectorcardiographic monitoring predicts unfavourable outcome in patients admitted with probable unstable coronary disease *Cardiology*, **93**:183-190
- [2] Cohen A 1986 *Biomedical Signal Processing* (Boca Raton, FL., USA: CRC Press)
- [3] Del Aguila C 1994 *Electromedicina*. (Buenos Aires: Hasa)
- [4] Gill S, Haastrup B, Hagfelt T, Dellborg M, Clemmensen P. 2002 Continuous vectorcardiography is superior to standard electrocardiography in the prediction of long-term outcome after thrombolysis in patients with acute myocardial infarction. *Coron. Artery Dis.* **13**:169-75
- [5] Moro C, Hernández A, Madrid F, Garcia Cosio F. 2001 *Electrocardiografía Clínica*. (Madrid: McGraw-Hill / Interamericana de España)
- [6] Netter F. 1976 *Colección de ilustraciones médicas: Corazón*. (Barcelona: Salvat)

Acknowledgments

To Ekosur S.A. and its people, in particular to Juan Pablo Trípodí, Lucas Fal and Duilio Spalletta, who gave us their time and resources to undertake this project.

To Alicia Soler, Lina Jullier, Silvina Horovitz and Carlos Méndez for their invaluable assistance.

To the Public University of Argentina that, in spite of all odds, keeps providing a space to generate and promote knowledge.