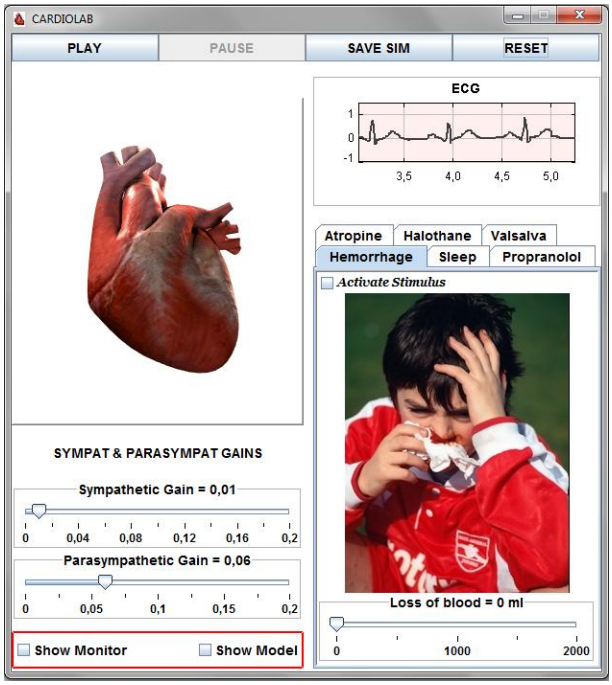
CardioLab User Manual

Computational tool for learning the cardiovascular system

Version 1.0 May 2011



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1. About CardioLab

CardioLab is a virtual tool designed to understand the functioning of the cardiovascular system in different conditions. This will eliminate the risks inherent in direct contact with patients, the high costs of materials and equipment to develop the testing and the possibility of wasteful tasks to carry out an experiment in optimum conditions. Therefore, the development of this virtual laboratory is not only an educational tool but also for research, allowing the study of drug effects on the cardiovascular system of clinics and the Valsalva maneuver and those physiological states that lead to the Sudden death.

The virtual laboratory is fully graphical and interactive; in the implementation of the mathematical model have been used Matlab R2009a (© The Mathworks Inc., Natick, MA) and the interaction between the user and the system have been built using EJS version 4.3.3.1.

1.1. *Cardiovascular System Model*

The model used in this work for the cardiovascular simulation was proposed by Limei Cheng in 2007 under the direction M. C. K. Khoo (Pneuma version 2007). This model consists of a set of modules that are used to simulate the autoregulation of the cardiovascular and respiratory systems under conditions of changing sleep-wake state and a variety of physiological and pharmacological interventions.
It models the dynamic interactions that take place among the various component mechanisms, including those involved in the chemical control of breathing, heart rate, and blood pressure, as well as the effects of changes in the sleep-wake state and arousal from sleep [1].

Pneuma includes the autonomic control of the cardiovascular system, chemoreflex and state-related control of breath-to-breath ventilation, state-related and chemoreflex control of upper airway pressure, as well as respiratory and circulatory mechanics. The model is capable of simulating the cardiorespiratory responses to sleep onset, arousal,

mechanical ventilation or continuous positive airway pressure, and the administration of inhaled carbon dioxide and oxygen.

Pneuma can be downloaded here:

http://bmsr.usc.edu/Software/PNEUMA/PNEUMAsoftware.html

1.2. *Interventions*

CardioLab allows to apply to the cardiovascular system a set of stimuli, drugs and maneuvers in order to study the cardiovascular system response in an interactive way for learning and research processes. The CardioLab version 1.0 includes the following interventions:

- *Valsalva Maneuver*
  This maneuver is used in clinical practice to explore the parasympathetic system state. It consists in making a forced inspiration against the closed glottis (like during cough events or the defecation).

- *Atropine*
  The Atropine is anticholinergic drugs, it acts concerning the organs and a blocking one of the muscarinic action of the acetylcholine (Ach), that is to say, inhibit the function of the parasympathetic system.
  The dose of atropine for a healthy subject of 70 kg of weight is between 0.5 to 3 mg.

- *Propranolol*
  The Propranolol is part of the antiadrenergic medicines, which interrupt or block the actions of the sympathetic nervous system, to avoid possible physical disorders, like cardiac hypertension or diseases.
  The dose of propranolol for a healthy subject of 70 kg of weight is between 42 to 120 mg.

- *Halothane*

  Halothane is an inhalation anaesthetic agent that causes a reduction in driving, causing sinus bradycardia and also produce QT interval prolongation.
  The alveolar harassing concentration (MAC) of the halothane is of 0.75 %.

- *Sleep*

  The cerebral activity presents displays manifolds possible states as the dream, the wake, the extreme excitation, and even the diverse moods of a person, among them the euphoria, the depression and the fear.
  The dream is the unconsciousness state that can be waked up a person by means of sensitive stimuli of another type.

- *Hemorrhage*

  Hypovolemia means diminished blood volume. Hemorrhage is the most common cause of hypovolemic shock. Hemorrhage decreases the filling pressure of the circulation and, as a consequence, decreases venous return. As a result, the cardiac output falls below normal, and shock may ensue.

2. Installing and Running CardioLab

CardioLab can be run under any operating system that supports the Java virtual machine and MATLAB / Similink. This paragraph describes the installation process, assuming you're using the Microsoft Windows 7 OS; users on other platforms can be clear about the process but with respective changes.

To begin using CardioLab its computer to have installed a version Matlab / Simulink higher or equal 7.1 and the Java Runtime Environment (JRE). You can check if Java is installed on your computer with the following link:

http://java.com/en/download/installed.jsp

If not installed, you can download and install on your computer.

It verifies that the surroundings variable "PATH" it corresponds to the location where it installed Matlab, for example:

C:\Archivos de programa\MATLAB\R2009b\bin\win32;
C:\Archivos de programa\MATLAB\R2009b\bin

The surroundings variables are in the Control Panel → System Configuration/Options advanced → Surroundings variables.

If the variable "PATH" it does not correspond to the indicated, modifies the variable according to the directory where Matlab was installed in its computer.

2.1 Installation

Run the Cardiolab installer. Choose the location on your computer where you want to copy CardioLab and select the files to be copied.

The installer shows step by step the installation process (see *Figure 1*).

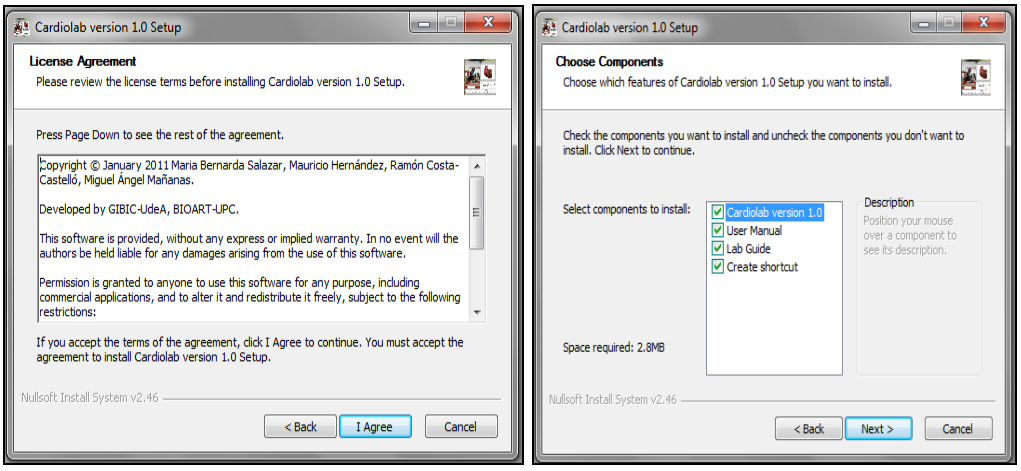


Figure 1. *Cardiolab installer. GNU license agreement and step by step installation*

All in all, if you followed the installation instructions provided and cannot get CardioLab to run, please send a message to mariabda2@gmail.com with a simple description of the problem, including any error message you may have gotten in the process. We'll try to help you as soon as possible.

2.2 Running Cardiolab

When CardioLab is installed, it will appear the windows message about there is new software installed in your computer. In this case it is true; one CardioLab Shortcut will appear in your program list (see *Figure 2*).

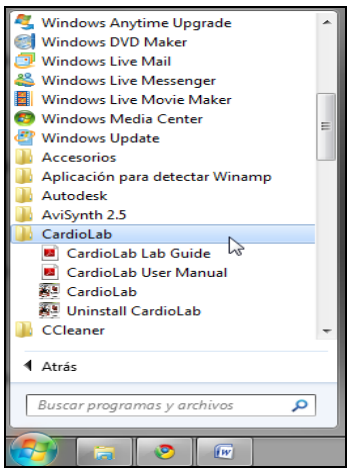


Figure 2. *Start Menu, the Shortcut to CardioLab, the Uninstaller and documents*

Double clicking on "CardioLab.jar". Immediately, you may click <play> button to start connection with Matlab and the application will run.

3. Interactive Panel

Interface of the virtual laboratory is shown in *Figure 3*. A big picture of one heart is shown in the top left. The interactive module is on the left side where interesting

parameters sympathetic and parasympathetic system can be changed by means of sliders in order to simulate different cardiovascular conditions.

A multisignal scope can be seen in the bottom left side of the interface when the user selects:

<*Show Monitor*> as external panel on the right side the screen with the signals arterial pressure, heart rate, cardiac output and respiratory frequency

<*Show Model*> as external panel with of model Pneuma 2007 (the MATLAB/Simulink model is shown)

The interactive module is composed by two important types of simulations:

- Change in the gain of sympathetic and parasympathetic system.
- Cardiovascular stimuli such as sleep, atropine, halothane, hemorrhage, Valsalva maneuver and propranolol (see *Figure 4*).

In the first one, two physiological parameters can be modified simultaneously: Gain sympathetic between 0 and 0.2 and the gain parasympathetic in the range of 0 to 0.2

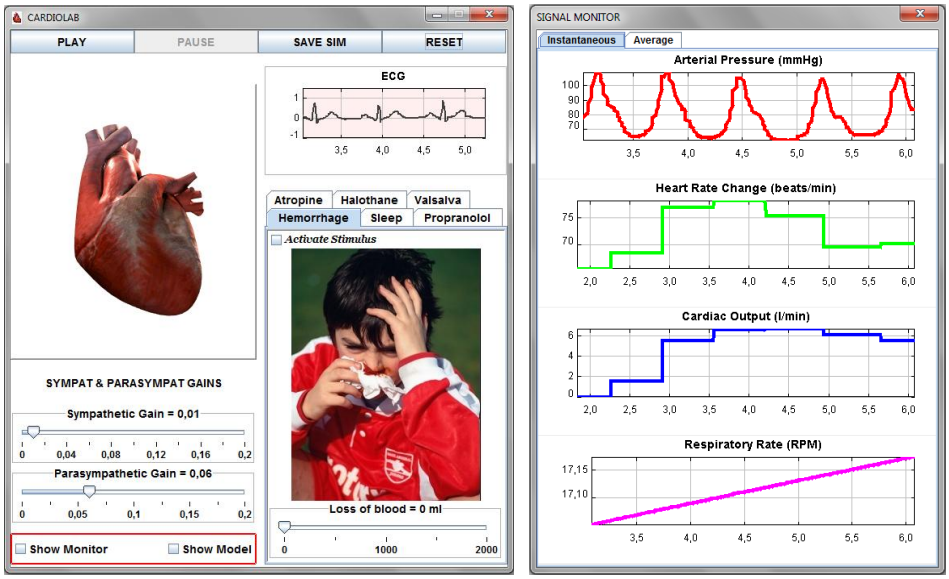


Figure 3. *Interface of CardioLab. Interactive Module is shown on the left side and the signal monitor on the right. Note the selected external panel is "signal monitor"*

Apply to any stimulus should select the "Activate Estimulus" in each case. Otherwise, variations in the slider will not affect the system.

For the case of the stimulus "Valsalva" the value "Start" and "Duration" must be indicated before pressing <*Play*>. The activation of the stimulus is due to do after the connection with Matlab finishes.

Finally, standard options in Virtual Laboratories are provided such as to <*play*>, to <*pause*> to <*reset*> and to <*save*> the simulation at any moment. The <Save-Sim> button allows saving the simulation for future analysis or comparison with real data.

(a) (b) (c)

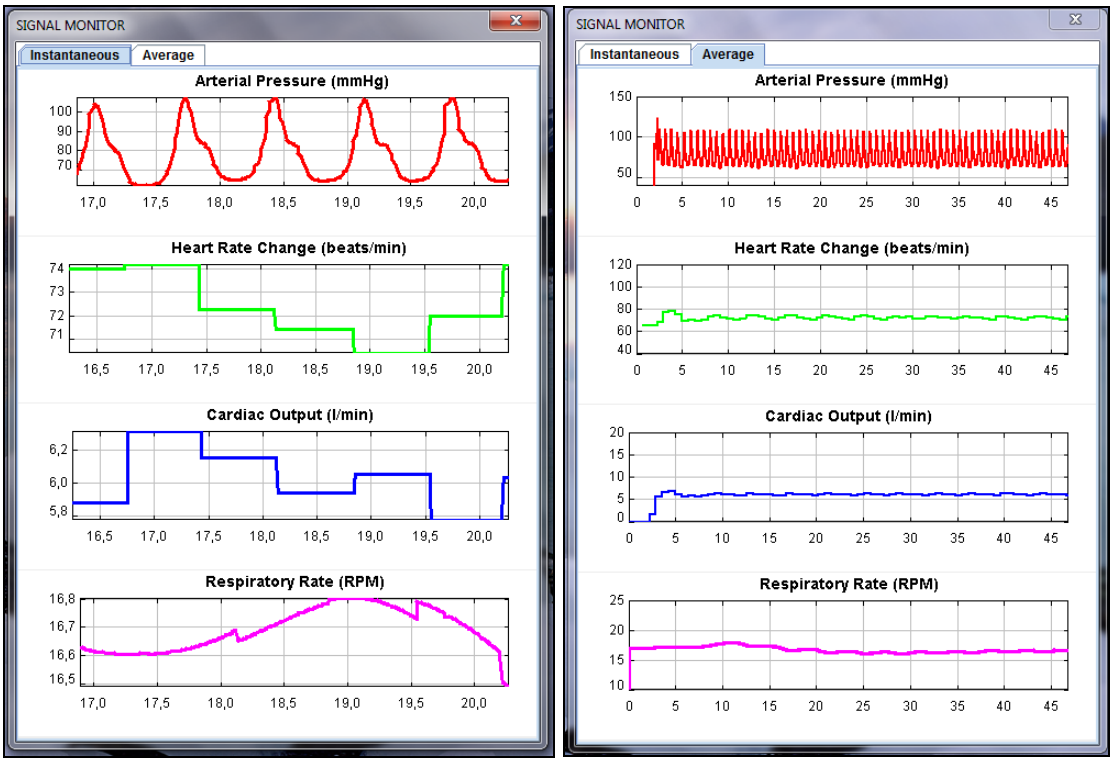
(d) (e) (f)

Figure 4.*Tabs of Cardiovascular stimulus: The animated pictures represent Hemorrhage in (a), Sleep in (b), Propranolol in (c), Atropine in (d), Halothane in (e) and Valsalva Maneuver in (f).*

4. Signal Monitor

One of two kinds of plots is shown when the corresponding tab of <Show Monitor> is selected by the user: Instantaneous and Average.

In the Instantaneous option, following variables are shown in the real time: arterial pressure, heart rate, cardiac output and respiratory frequency (see *Figure 5.a*).



(a) (b)

Figure 5. (a)*Tab of Instantaneous values in the Signal Monitor panel. (b) Tab of Average values in the Signal Monitor panel*

In the Average option, changes of variables are observed to spend a long period of time: arterial pressure, heart rate, cardiac output and breathing frequency (see *Figure 5.b*). You can analyze their behavior in time after applying a stimulus.

5. Simulink Model

When the external panel <Show Model> is selected, the Simulink model will appear, but <*play*> should have pressed, the connection running Matlab first (see *Figure 6*).

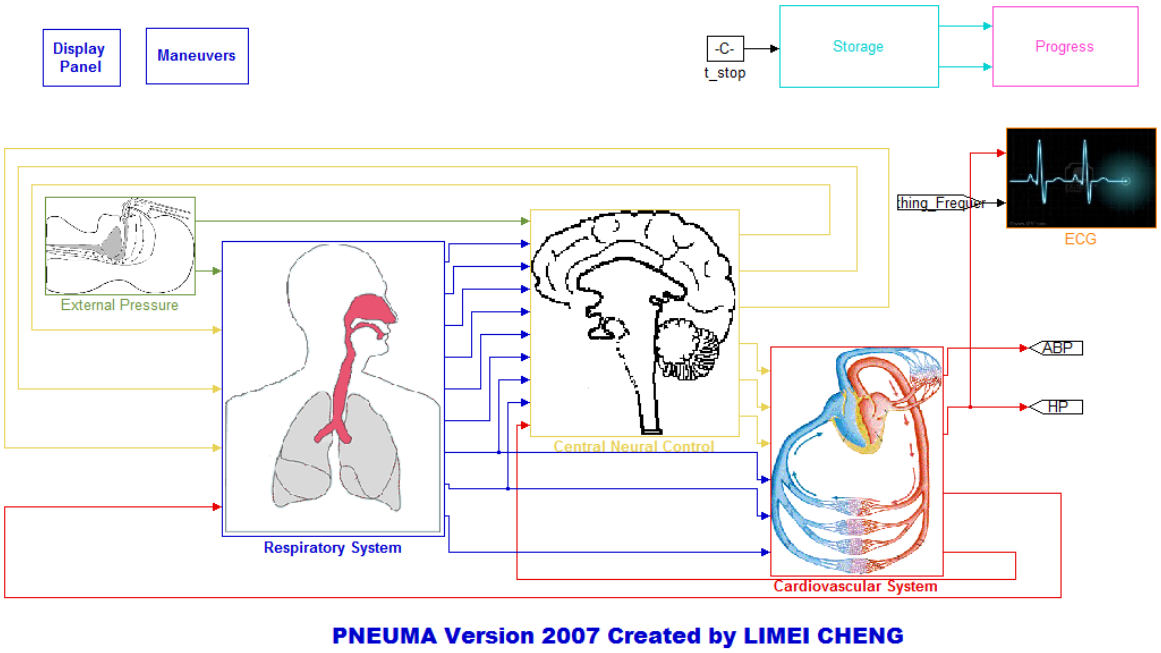


Figure 6. *Simulink model. Note the blocks Display panel, Maneuvers, Storage, Progress, Respiratory System, Central Neural Control, External Pressure, ECG and Cardiovascular System.*

Simulink model is composed by five subsystem block masked to prevent the non intentional modification.

The cardiovascular system model selected to build CardioLab is described by Khoo [1]. The Simulink model includes generation of ECG using a model developed by McSharry [2] and implemented by the GIBIC researcher bioengineer Camacho Alejandro in the Modeling and Simulation course of the Master of Engineering at the University of Antioquia.

6. Saving Simulation Data

The data resulting of the simulation can be saved through of the Matlab commands. In the workspace are shows all resulting variables of the simulation. These can be saved

pressing the SAVE SIM button and writing (see *Figure 7***¡Error! No se encuentra el origen de la referencia.**):

"file_name.mat"

Where file_name is the file name whose extension is .mat.

The SAVE SIM button is available only when the simulation is paused. The variables that are stored on the site chosen are:

- Time *Time*
- Blood pressure *ABP (mmHg)*
- Heart rate *HR (beat/min)*
- Cardiac output *CO (mL/min)*
- Breathing Frequency *BF (breaths/min)*
- *Electrocardiogram* *ECG*

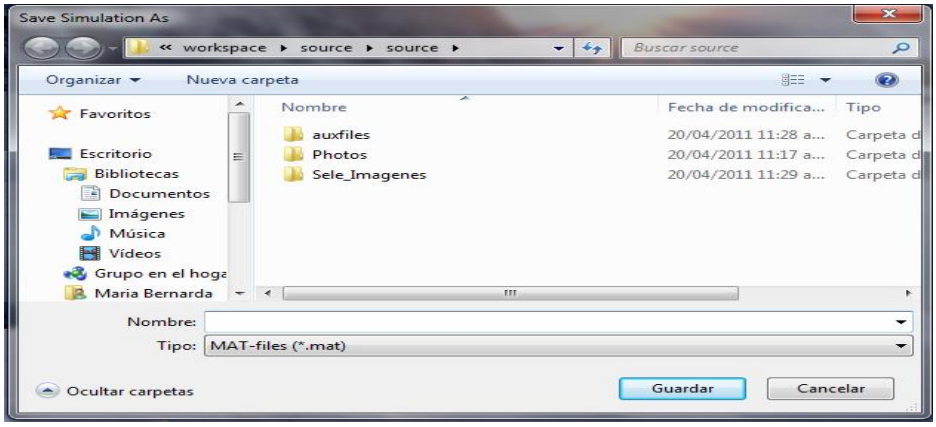


Figure 7. *Saving simulation data: clicking on <Save-Sim> button, the window "Save Simulation as" will appear.*

7. Contact and Support

For questions and suggestions about CardioLab can be send it your valuable comments and feedbacks to mariabda2@gmail.com or mhernand@udea.edu.co Once we have the solution, then we will post it so that other users can benefit from it.

8. References

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