

ECG tutorial

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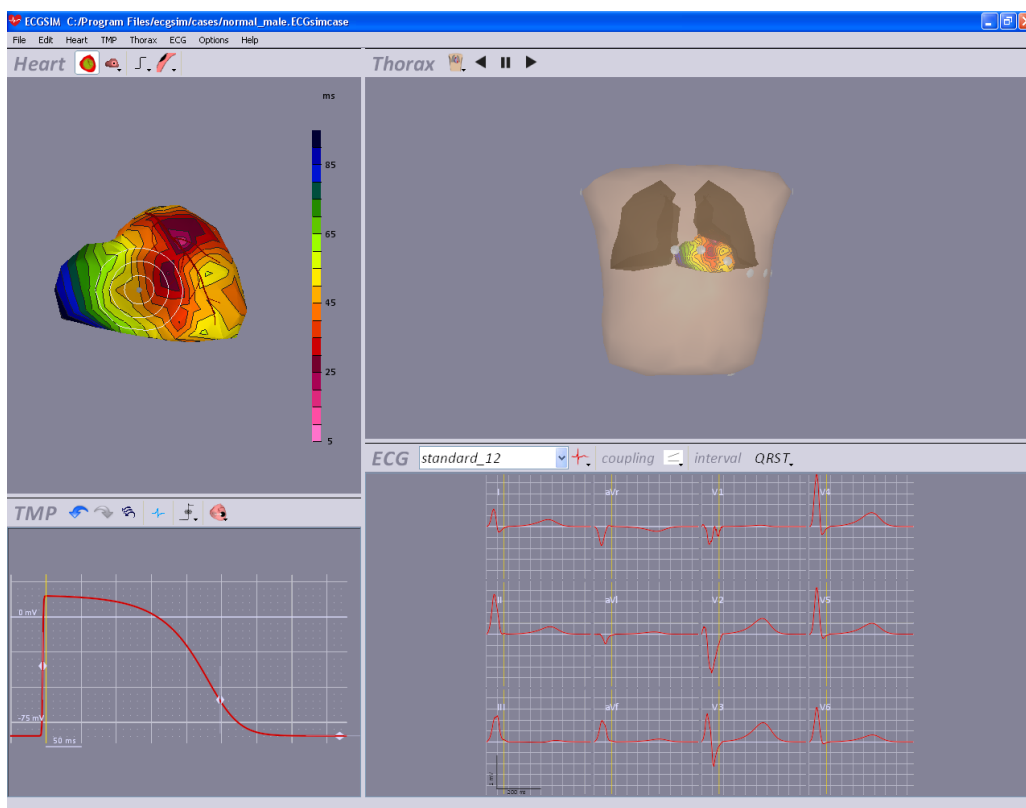
1 Introduction

ECGSIM allows the user to view the effect on the ECG of changes in the electric activation of the heart. The purpose of this tutorial is to make the user familiar with the controls of ECGSIM. It is not a course in ECG interpretation. Neither does it explain the theoretical basis of ECGSIM (for that purpose, read the introduction of the ECGSIM manual — accessible from the help menu — and the references listed in the manual).

2 Layout of the main window


When ECGSIM is started, you see something like figure 1. The main window is divided into 4 panes: the heart pane (top-left), thorax pane (top-right), membrane pane (bottom left) and ECGs pane (bottom right). At the top of the window there is a menu bar, that gives access the menu items that control the program. Each pane has it's own tool bar with buttons that provide access to the most frequently used functions..

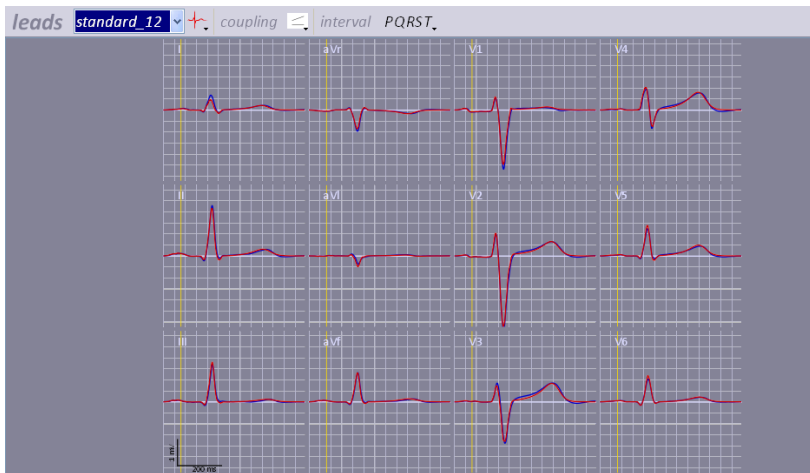
The relative sizes of the panes can be changed by grabbing the bars that separate the panes, and then move the mouse while holding down the mouse button (“dragging”).



Figur 1 The main window

3 ECGs pane

Let's first take a look at the ECGs pane (figure 2). By default it displays the simulated ECG in the 12-leads system. Later this manual we will explain what the simulated ECG is. For now, we'll turn to the reference ECG. Click the button , and check the option "Measured ECG". Now the pane also shows (in blue) the measured ECG of the subject on which the model built into ECGSIM. As you can see, there is a good match between the measured and the simulated ECG.




Figuur 2 The ECGs pane.

In white the "Initial ECG" is displayed. You don't see that now, as it coincides completely with the simulated ECG. Later on, we will change the simulated ECG, and the initial ECG will become visible. The yellow bar in the ECG's pane is a time marker, the purpose of which will become clear later on. The scale of the ECGs is changed by means of the mouse wheel.

4 Thorax pane

In the thorax pane a thorax model is displayed. This is the thorax of the same subject whose measured ECGs are displayed in the ECGs pane. The model was constructed on the basis of MR images. The metallic knobs at the front of the thorax indicate the positions of the standard ECG leads V1 to V6.

By dragging with the right mouse button you can rotate the thorax. Double clicking restores the standard frontal view.

In the ECGs pane the electric potentials measured at the standard leads are displayed. For the subject in question, the ECG was measured not only at the standard leads, but at 64 electrodes distributed over the front and back of the thorax. You can view the measured potentials on the thorax as a so called Body Surface Map (BSM) by clicking the button , and choose "Measured BSM". The bar at the right shows the color scale; blue for negative potentials, red for positive and green for zero. Again, use the mouse wheel to change the scale.

The yellow vertical bar in the ECGs pane indicates the time instant for which the potentials are displayed in the thorax pane. You can move through time by pressing the arrow left and right keys on the keyboard. You can also click or drag the mouse in the ECGs pane to change the time instant for which the potentials are displayed.

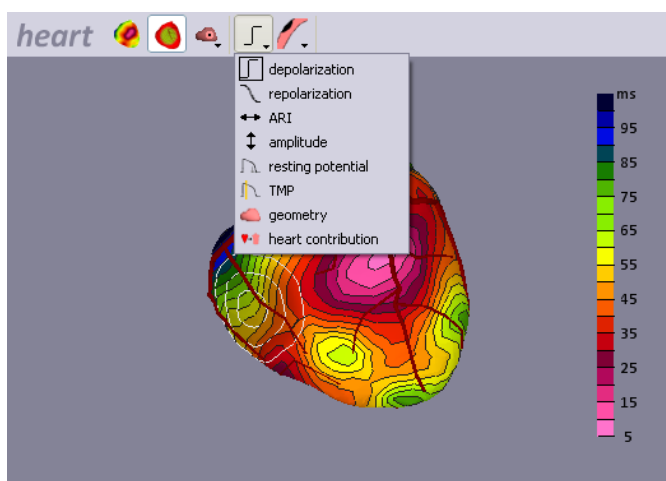
If you click the ► button, the BSM is displayed as a movie. You can change the speed and time interval of the movie in the Options, Movie menu, which brings up the movie properties dialog window.

5 Heart and membrane panes

In the heart panel the ventricles are displayed (for some cases the atria are included, and can be displayed separately). To aid orientation, the Left Arteria Decendens (LAD), which runs along the boundary of the left and right ventricle at the front of the heart, is also displayed.

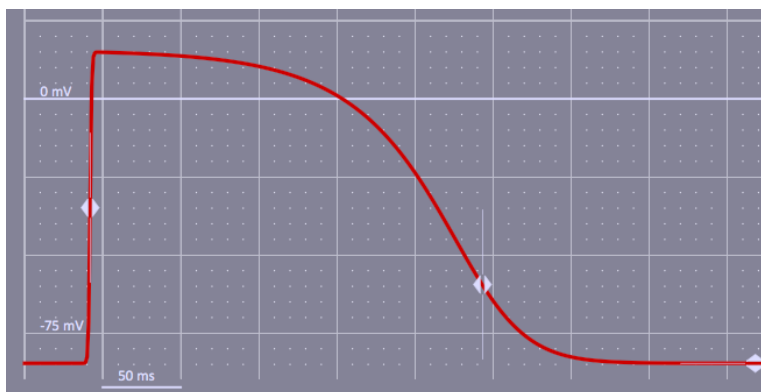
Use the right mouse button to rotate the heart, in order to look into the ventricles. What you see is actually the surface of the ventricular myocardium (heart muscle). The valves through which the blood enters and leaves the heart (that are all located at the top) are not displayed. Double click to return to frontal view.

You can choose what to display on the heart surface from the drop-down menu activated from the toolbar (figure 3).



Figuur 3 Heart panel, with the choice what to display on the surface.

Choose to display the geometry. The triangulated mesh that represents the myocardial surface will be visible. Left-click on the heart surface. This selects the nearest node on the heart surface, as indicated by a marker. A region around the selected node is marked by concentric circles.



Figuur 4 Membrane pane.

When a node at the heart is selected, the membrane panel displays as a function of time the transmembrane potential (the voltage over the cell membrane) for the heart cells at that node (figure 4). In rest, the transmembrane potential is -90 mV. When the cell is activated

(depolarized), the transmembrane potential rises sharply to 10 mV. Subsequently, during the repolarization phase, it gradually returns to -90 mV.

Move to the heart pane, and select different nodes at the heart surface. Note that the depolarization and repolarization times differ between nodes. The depolarization of the cell membrane of a myocardial muscle fiber initiates the contraction of the fiber. Hence the sequence of depolarization corresponds to the sequence of contraction of the myocardium.

You can display a map of the depolarization times at the heart surface by selecting “depolarization” in the heart tool bar (figure 3). Note that the earliest activation is at the left ventricular septum, and the latest in the outflow area of the right ventricle. You can also display the repolarization time, or the duration of the depolarization (ARI).

6 Simulated ECG

Now we come to the main feature of ECGSIM. Doubleclick in the heart pane to reset to frontal view, display the depolarization times, and select a node at the front of the heart (figure 3).

In the membrane there are three handles attached to the transmembrane potential wave form. The left-most one indicates the depolarization time of the selected node. Drag the handle with your mouse. You will see that the depolarization time of the selected node is changed to the value where you set the knob. Also, the depolarization times within in the range of the selection change with an amount that is zero at the rim of the range and maximum at the center (the selected node).

Click the undo button in the toolbar of the membrane pane. Now change the depolarization time again, and observe what happens simultaneously in the ECG;s pane: the ECG that is displayed in red is the ECG that ECGSIM computes from the transmembrane potentials at the heart, as defined by the current values of the depolarization times and repolarization times. When the user changes the parameters that describe the transmembrane potentials, ECGSIM recomputes and redisplay the simulated ECG immediately.

You can now play around with the effect of changes in the depolarization and repolarization times in different regions of the heart. For instance, you will see that for some regions changes have a much larger effect than for other regions. Consequently, the standard 12-lead ECG is much more sensitive to some regions of the heart than to others. The “Undo” button undoes the most recent changes. Click that button repeatedly to move back in time. The “Undo All” button undoes all changes.

You can modify the size of the range around the selected node by using the mouse wheel. There are 2 different ways in which ECGSIM determines which nodes fall within the selection range. In the first method, the shortest distance along the surface of the myocardium between a node and the selected node is computed, and if this distance is smaller than a certain value, the node is within the range (this is the default method). Changes made in this mode only extend along the surface around the selected node.



Figure 5 Wall selection.

In the second method the shortest distance through the myocardial tissue is computed. In this way transmural changes can be made. Figure 5 shows that you can turn the transmural mode on or off. Also, in non-transmural mode you can mode the selection to the other side of the wall by choosing “switch wall side”.

7 Some exercises

Acute myocardial ischemia

In the case of acute myocardial ischemia, the amplitude of the action potential in the ischemic region decreases (more precise: the transmembrane potential in the resting phase becomes less negative). To simulate the effect on the ECG of acute ischemia, select a node at the heart, at the position indicated in figure 2. Choose the size of the range as in that figure. Use the vertical handle at the right in the membrane pane to decrease the action potential amplitude. In the simulated ECG you will see that the signal does not return to the baseline between the depolarization phase (QRS-complex) and the repolarization phase (T-wave). This effect is called ST suppression or elevation, and is typical of acute ischemia. If the selection range is small, the effect is only visible in the electrodes close to the infarction. As the size of the range is increased, the effect becomes visible in other leads as well.

If the infarction is transmural, the tissue both at the outside (epicardium) and inside (endocardium) is affected. If it is not transmural, only one side is affected. To simulate transmural infarction, choose “transmural” in the wall selection menu.

Bundle branch block

If a bundle of the Purkinje system is blocked, the depolarization of the region of the heart that is served by this bundle is delayed. To simulate a left bundle branch block, select a node at the top of the free left wall, and set the size of the selected region so that it encompasses most of the left free wall. Set the depolarization time of the selected node to about 180 ms. You will see all typical effect of a left bundle branch block: elongation of the QRS-complex, and more negativity (or less positivity) in V_2 to V_5 .

Hypertrophy

In the case of right ventricular hypertrophy, the thickness of the right ventricular wall is increased. As a result, it takes longer for the depolarization wave front to spread from the endocardium to the epicardium. Hence, the depolarization times at the endocardium are normal, and those at the epicardium are late.

To simulate right ventricular hypertrophy, choose a node on the middle of the right free wall. Uncheck transmural selection, as we will want to change the activation times on the outside only. Delay the depolarization of the selected node. The late part of the QRS-complexes in V_1 to V_2 will become positive, which is commonly observed in the case of right ventricular hypertrophy.

8 Moving on

ECGSIM has far more possibilities than explained in this tutorial, but you should be able to explore these for yourself. A good idea would be to study the manual, which is displayed if you choose Manual from the Help menu.

We hope you will enjoy using ECGSIM .