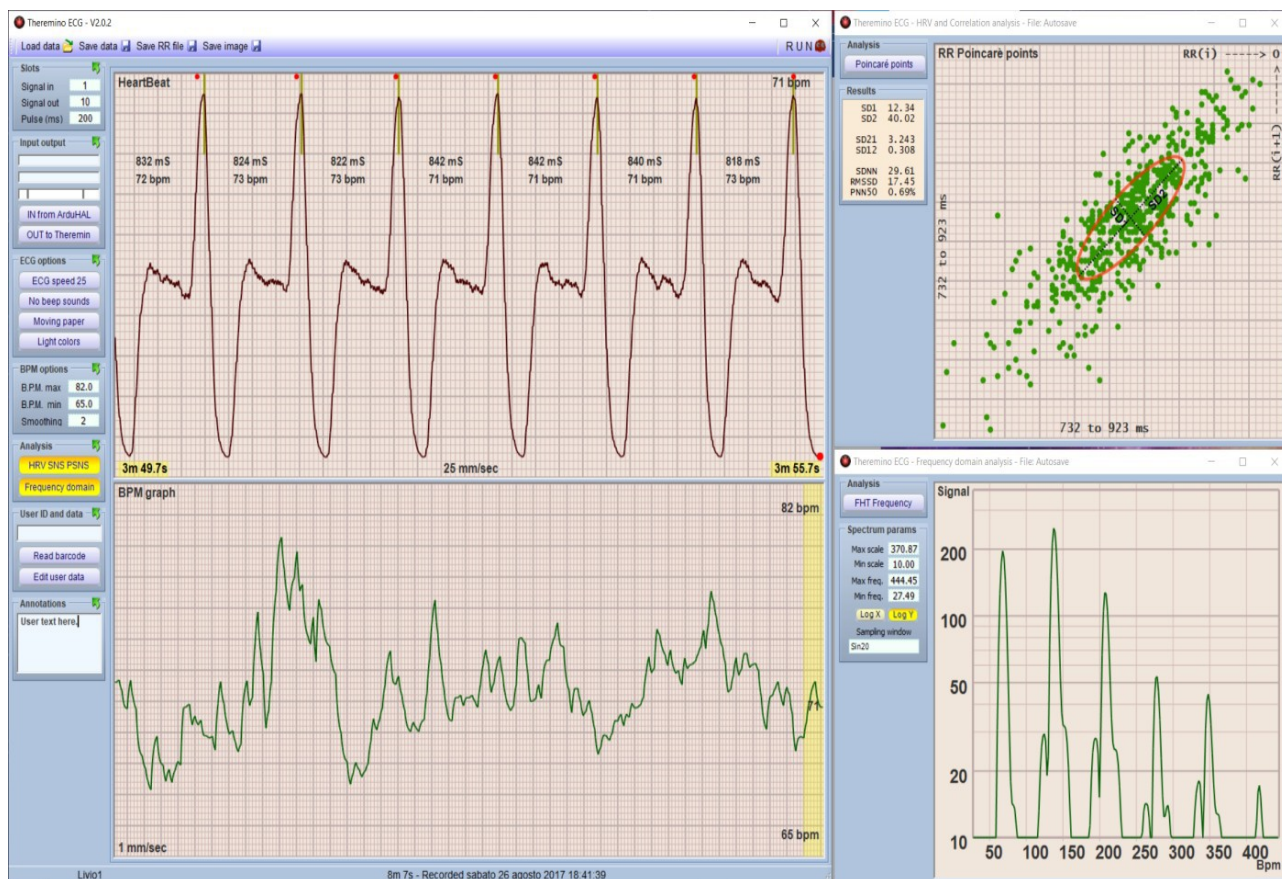


theremino System



Theremino ECG V2.0

Index

Introduction.....	3
Characteristics.....	4
Installation.....	5
Folder structure.....	6
Main dialog.....	7
Vertical menu bar.....	8
Starting the program.....	16
Start recording.....	17
HRV analysis SNS PSNS.....	18
FHT spectral analysis.....	20
Adjustments and artifacts.....	22
Technical notes.....	27
Shape of the ECG & OCG signals.....	28
Arrhythmia examples.....	29

Introduction

A few years ago, we presented the program: "THEREMINO ECG", capable of reading and processing different cardiac electrical signals, coming from various input sources. Next we addressed the topic of HRV(*Heart Rate Variability*) i.e. the variation of the intrinsic frequency of individual heartbeats. This branch of science, by studying the correlation of the variability of the traces and making use of special evaluation software, tries to establish a possible causal link with the various vascular diseases, metabolic diseases (diabetes), but also psychic disorders and use in holistic medicine, but equally useful in the behavioral study of sports activities. For further information, please read the [in-depth pages](#).

At that time we suggested to use the KUBIOS software for in-depth and professional analyses, because it is well structured and complete, offering the possibility of performing dozens of various types of analyses. Many doctors, physicists, psychologists then wrote to us telling us, this software is very beautiful, but so complex to use and also the many often unused functions, in the end do not promote its use in an appropriate way.

After having analyzed and evaluated various possibilities, having heard the opinions of various professionals and experts in the field, we undertook the creation of our own software that was simple and easy to use but still performing and flexible as a whole. After a year of intense work, we have finally come to issue the ECG 2.0 version, with completely revised functions and renewed graphics.

Obviously like everything we develop, this software is too **entirely free, open source** and therefore completely open to exploration and analysis of the formulas used and above all it is a "*portable software*". A portable software is a program that doesn't have to be installed on the computer where it's used, just copy it to any folder, or to a pen-drive, and start it. There are no libraries or particular functions that impact on PC performance.

The program is simple, functional and light. In line with the philosophy of all our projects.

Characteristics

- Possibility of recording data for a few minutes or hours depending on the needs;
- Data can be scrolled back in time to locate significant points;
- Once the artifacts have been identified, they can be eliminated and saved as a "clean" file;
- Ability to archive files with a name, a date and a personal comment;
- Automatic creation of patient records with fiscal code;
- Health card and QR Code reading via webcam and automatic data entry;
- The data files to be processed are compatible with all analysis programs;
- Data files are compatible and usable for HRV analysis(*Heart Rate Variability*);
- Archived files include Poincaré, auto-correlation, SNS/PSNS ratio, and frequency;
- Automatic saving of the last file in the "Auto-save" folder in case you forget to give it a name.
- Various warning signals including the classic sound of ECG;
- User-specified limits and alarm sounds when limits are exceeded;
- Ability to create musical melodies at heart rate via Theremino Theremin;
- Availability of some per-built analytics tachograms for didactic and study purposes;
- Ability to create customized simulation files (*in from simulator*);
- Display on classic dynamic or static graph paper;
- Precise synchronism keeps the pulses perfectly still so as to highlight changes reducing eye strain;
- Trigger key to sync progress / beat during recording
- Light background like graph paper ECG or dark, like electronic instrumentation;
- Two classic speeds of 25 and 50 mm per second;
- Special speed of 10 mm/sec. useful for scrolling long periods and identifying arrhythmias;
- Automatic calculation of milliseconds and beats per minute(*no need to count the squares*).
- Indicators synchronized with the frequency of the last beat to highlight changes.
- Display of beat RR intervals greater than 50 ms (NN>50)
- Automatic control of width and vertical position. This automation constantly maintains maximum visibility of the pulse shape and highlights arrhythmias (*this device does not replace classic ECG but performs analyzes for which the amplitude and vertical position are not significant*);
- Optimized controls and windows that can also be used on a tablet's touch screen.

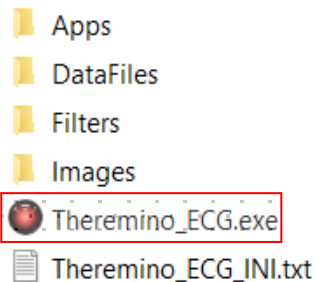
Installation

The program: **Theremino_ECG_V2.0.zip**, downloadable from [This Page](#) it must first be unpacked and then copied in its integral configuration, preferably in its own folder, for example **C:\UserName** and not under folders used by Windows like: "Program Files", "Users" or "Desktop"

We will find with a structure as in the image where inside the folder: **Theremino_ECG_2** is located the executable file: **Theremino_ECG.exe**.

At this point, for convenience we can create a shortcut of this executable and to copy it to desktop.

Nome



Double click left mouse button will launch the program.

If we want to uninstall the software, just take the root folder and move it to the Recycle Bin and that's it. In the same way we can simply move it to another destination, redo the connection and everything will work normally, like before.

*Exclusive peculiarity of this program, like all theremino system programs, is when you close the application using the top right button marked with an X, **the system will remember all the settings** previously used, such as windows, their positions and sizes, data set, last analysis performed, and so on.*

The next time the program is reopened, we will find with the exact same closing screen.

Folder structure

In folder **Apps**, we find various programs we need for the various input interfaces and in detail:

- **Theremino_ArduHAL**: connect HW Arduino input
- **Theremino_Automation**: Create sampling waveforms
- **Theremino_HAL**: connect HW, not Arduino, in input
- **Theremino_QR decoder**: reads QR codes and bar codes
- **Theremino_Theremin**: turns signals into music

Nome

- Theremino_ArduHAL
- Theremino_Automation
- Theremino_HAL
- Theremino_QRdecoder
- Theremino_Theremin

In folder **DataFiles**, we have all the data files.

- **Autosave**: inside is the last created file (backup)
- **Examples**: various sample and test files
- **Tachograms**: RR (NN) data is saved
- **Users**: Patient data is stored here

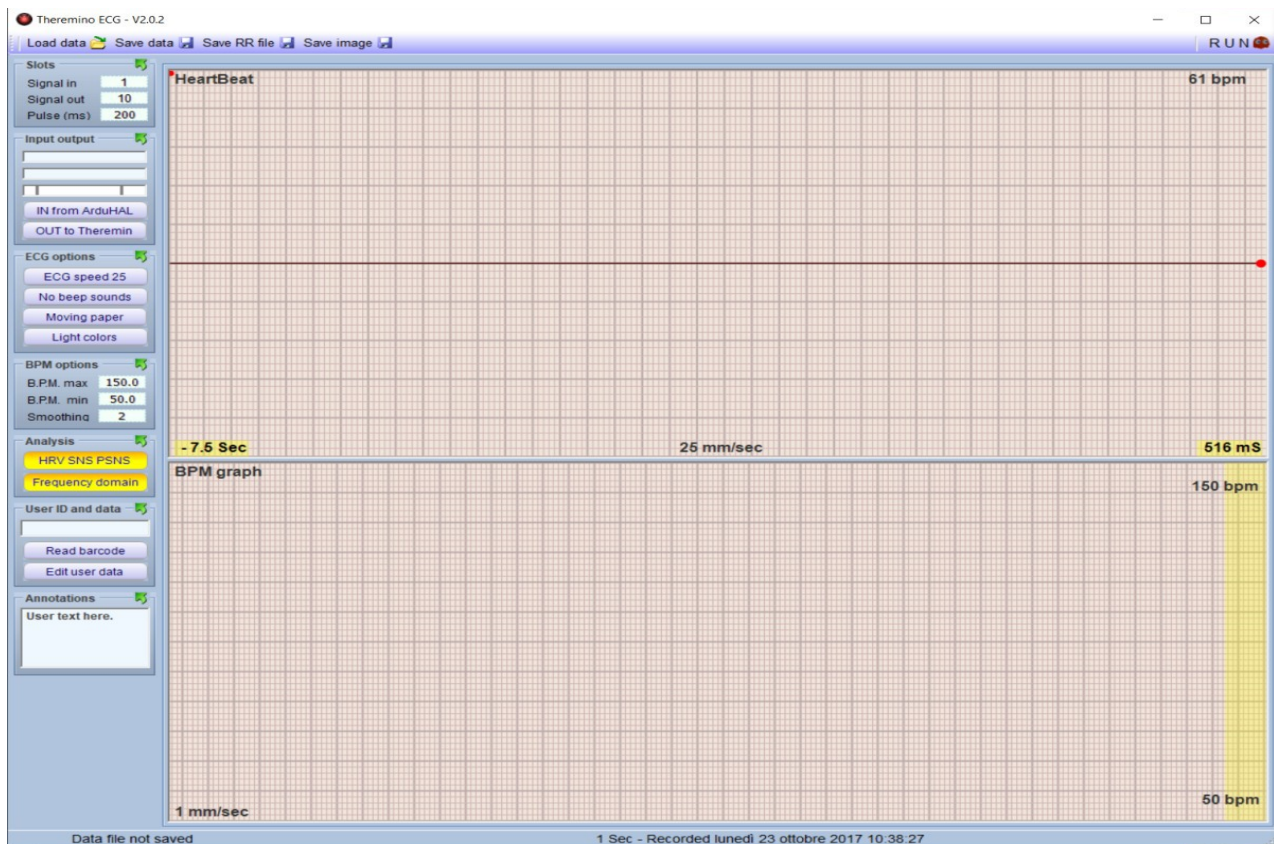
- Autosave
- Examples
- Tachograms
- Users

Finally the folder **Images**, stores image files of the screen (screenshot) acquired by pressing the button: **Save image** present in the dialogue bar at the top of the main window.



Main dialog

When you first start the program, a completely blank window will normally appear.



On the top we have the toolbar:



Load data, allows you to load previously processed files and examples, stored in the various folders so that they can be analyzed, reworked and reproduced.

Save data, allows you to save acquired or processed data files, in the appropriate folders which can be those with the data of the various patients or below, Examples.

Save RR file, save all the RR or NN data and then the data of each single pulse in seconds with three decimals up to milliseconds, in the tachograms folder.

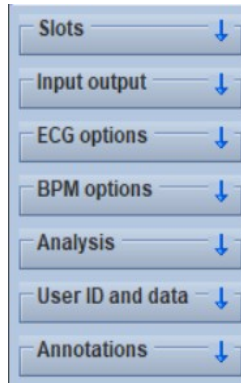
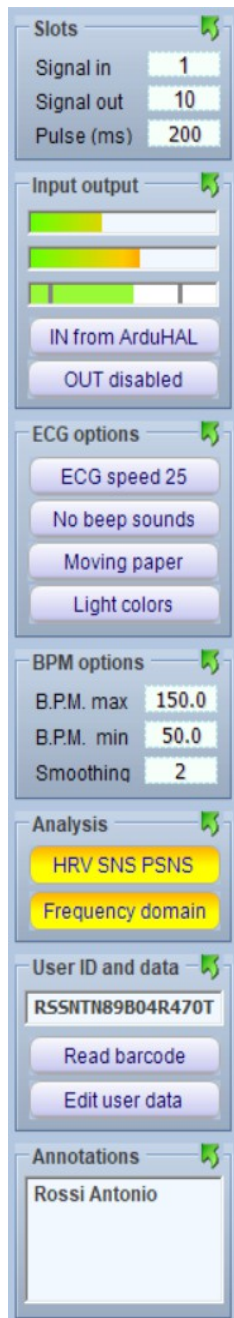
Save Images, as we have already seen in the previous paragraph allows you to capture the *screenshots* of the window in use at the moment.

Help and Updates, through a link we arrive at the user manual and to the latest version download.

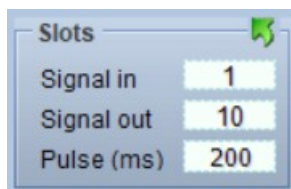
Finally, at the top right, we find the key **RUN** with which we can launch the program and stop it. When you start the program, other keys appear where we will explain them later

Vertical menu bar

To the left of the main dialog, we have the functional menu bar.



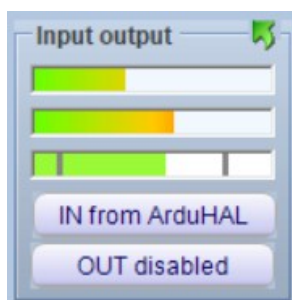
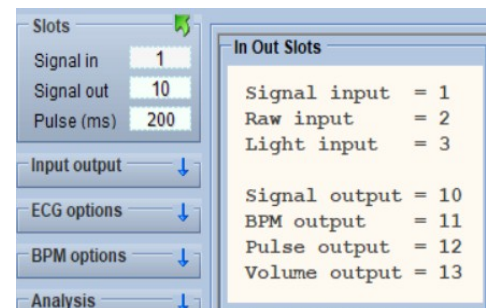
If you close all the communication windows by clicking on the various ones, we will end up with a profile as shown in the side, with seven main menus and that we will now analyze in detail one by one.



Slots

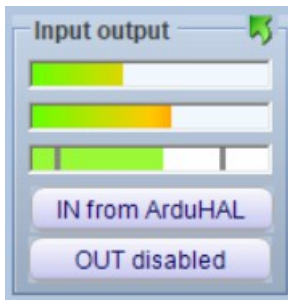
They are containers that receive the data is deposited (written) and that could be read to process all the various functions. By opening the window and positioning the mouse on one of the boxes, a second window opens, where the identification numbers of the slots used and the related memorized data are listed.

In the third cell "Pulse" you can enter a time in milliseconds which could be used for analysis and calculations for example through the use of "matlab". Normally this dialog can be kept closed.



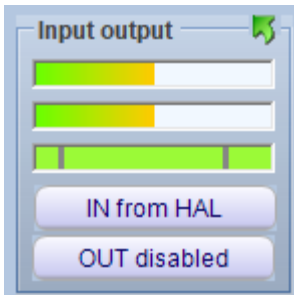
Input output

The three bars indicate the input and output signal levels. When using an ECG or OCG type signal detector applied for example to the finger, it's mandatory to verify the signal of the third bar (bottom) should always in the range between the two bar lines. Then we find a key, where it is possible to select in sequence using the mouse, four types of Input, such as: In from ArduHAL; In from HAL; In from Simulator; IN from file.

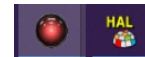


In from ArduHAL, allows you to connect devices with Arduino firmware, such as our OCG finger sensors, to the PC via USB port.

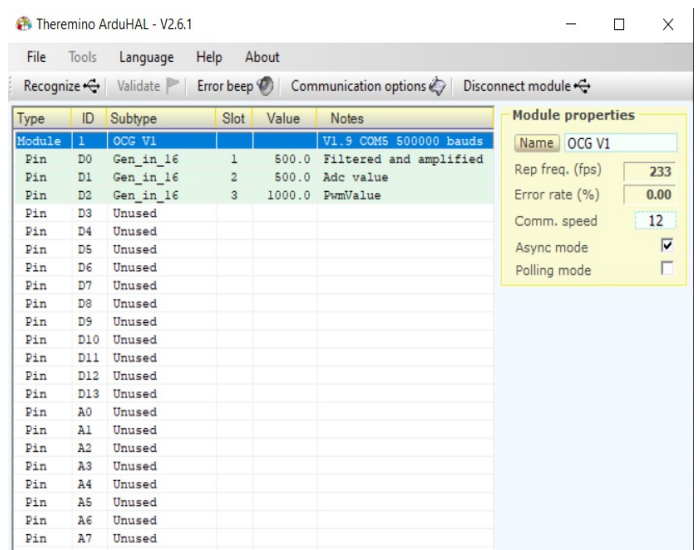
When using this input, on the application bar, near the Theremino ECG icon, the icon also appears: ARDU



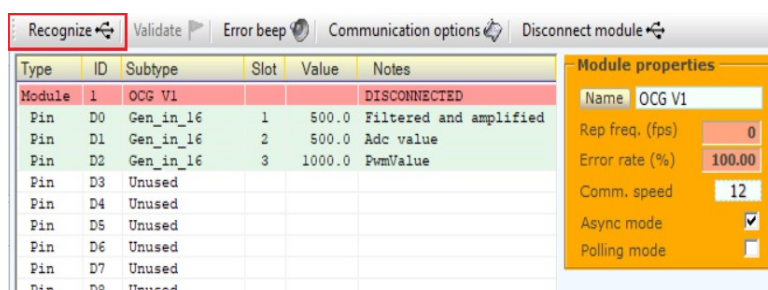
In from HAL, is used if sensors or ECG devices are connected, having output signals in Volts (0-10) or in mA (4-20), through our MASTER modules. When using this input, HAL also appears in the application bar, near the Theremino ECG icon

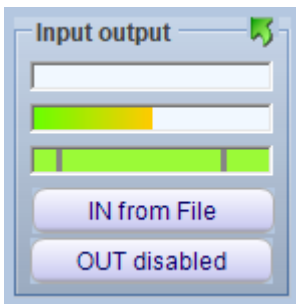


By clicking on the icons "**HAL or ARDU**", which we still recommend to keep iconized when not in use, a dialog window opens as shown in the following image, where the connections used in the HW, the name of the input device, the slots used and so on, are highlighted.

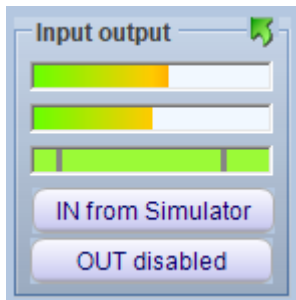


If the system doesn't recognize the USB port, the first line where it is inserted "**Module**", turns red, indicating "**DISCONNECTED**" and the window "**Module properties**" turns orange. In this case, click on "**Recognize**" and if u have working HW connected, everything should be fine.





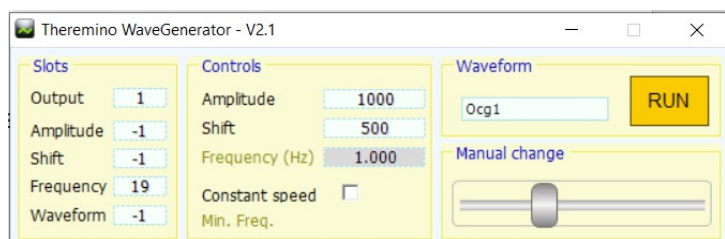
In from File, is used to read for example previously processed and saved files. The same, may then be entirely retraced, modified, analyzed and if necessary saved under another name, where desired.



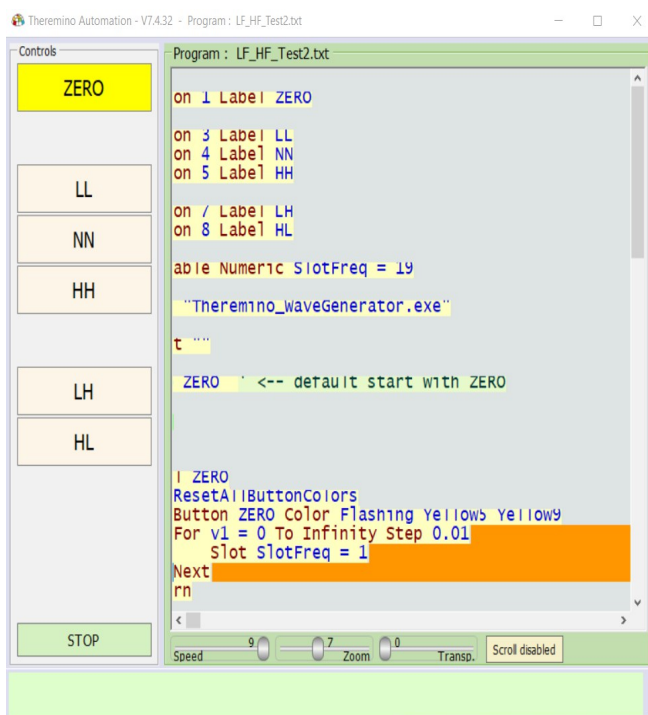
In from Simulator. By selecting this function, we have the possibility of creating and processing pre-built waveforms that are very useful for understanding the operating logic of the various LF and HF wave configurations. When we enable this feature, we will find ourselves on the taskbar with two new icons.



The first icon opens: **"Theremino wave generator"** which appears as show in the side view.

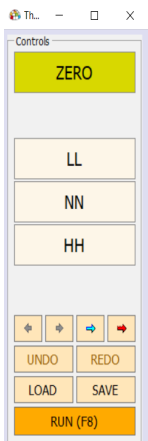


Inside it, we find several controls, which we recommend NOT touching except those below: "Waveform" where positioning on the window, we can enables a menu with constructed waveforms. However, the most interesting and used are: **ECG** and the **OCG**. The button **RUN** must always remain enabled, otherwise of course nothing will be played. We also recommend keeping this window minimized once set.



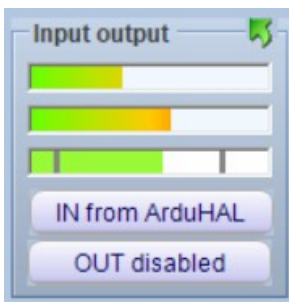
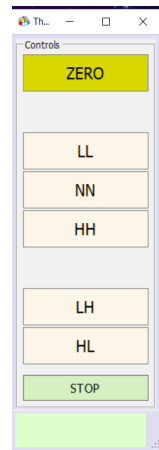
The second icon: **"AUTO"**, opens: **"Theremino Automation"**, a powerful software used in several sectors, such as CNC milling, robotics, etc...

The STOP is only used to make changes to the software. In the next chapters we will explain the different functions could be selected using the 6 keys: ZERO, LL, NN, HH, LH, HL.




We suggest reducing the window from right to left, so that only the vertical command bar remains and leaving the program always active, i.e. press **RUN** so that the button is green and "Stop" written on it.

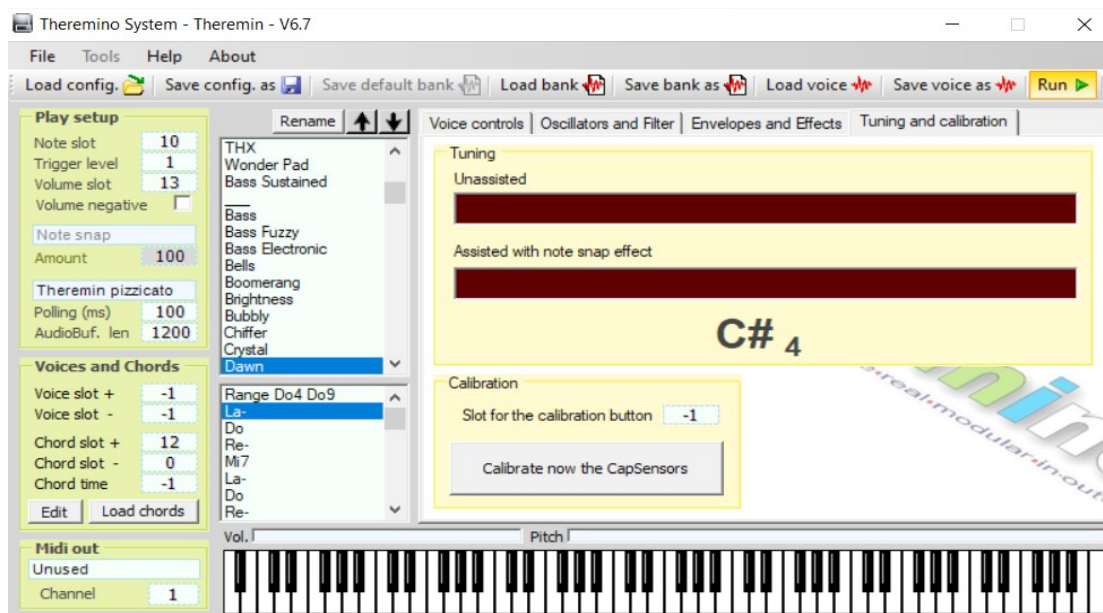
We also recommend not touching anything within the software unless you are an expert programmer, as it may no longer work.



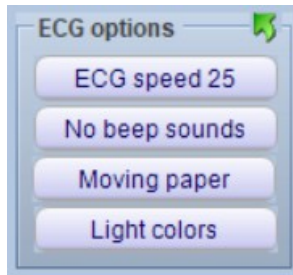
The second key: **Output disabled** or **Out to Theremin**, gives us the possibility of having no sound system output or the Theremin application.

Pressing it, an icon  opens on the application bar, and enables a powerful digital audio processing system which processes cardio signals and translates them into sounds processed through appropriate chords.

A virtually useful system for relaxing during analysis or just for entertainment.



In this application you may use the menu: **Load config.** to choose from a few ready-to-use configurations. With a little experience, you could even try creating and storing new effects. Naturally to operate, the key **RUN** must be active. Once the desired sound motif has been chosen, the window can be minimized to an icon, so that it doesn't take space on the monitor.



EKG options.

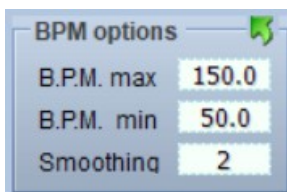
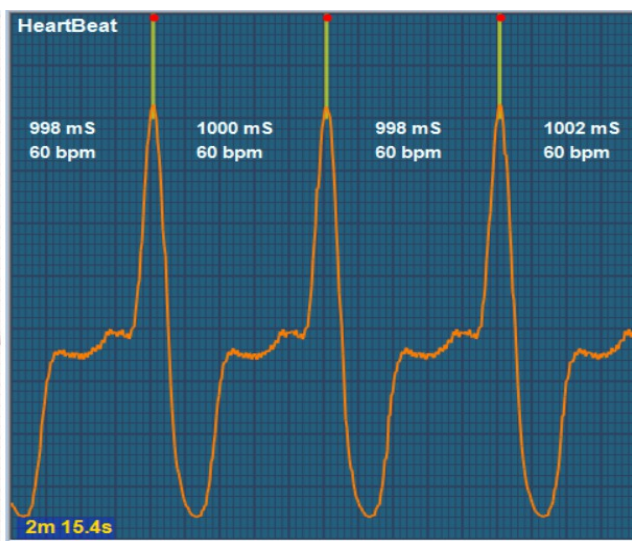
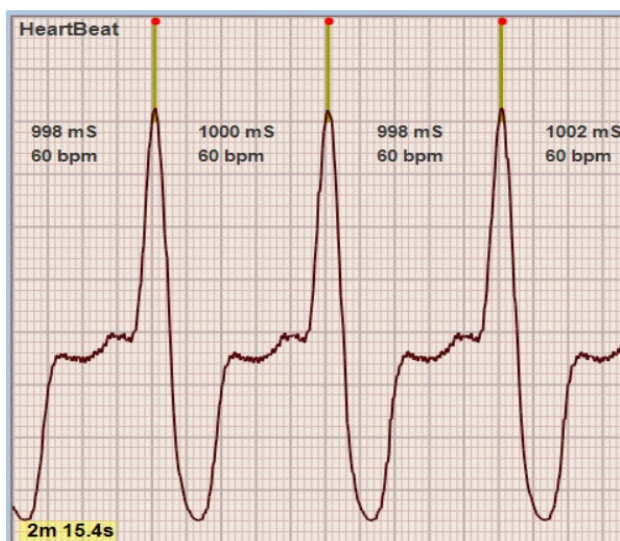
This window has 4 buttons.

The first button: **ECG speed...**, offers us the possibility to choose between 3 different advance speeds of the tachogram, such as: 10 mm/sec. – 25mm/sec. – 50mm/sec.

Using the second button you can select the acoustic signals and possible alarms, i.e.: **Beep only; Beeps + alarms; Alarms only and No Beep Sounds.**

With the third button: **Static papers** or **Moving papers**, we can simulate the scrolling or static paper.

Finally the fourth button: **Light colours** or **Dark colors**, offers us the colors of the classic ECG paper or those of electronic instrumentation.



Bpm options.

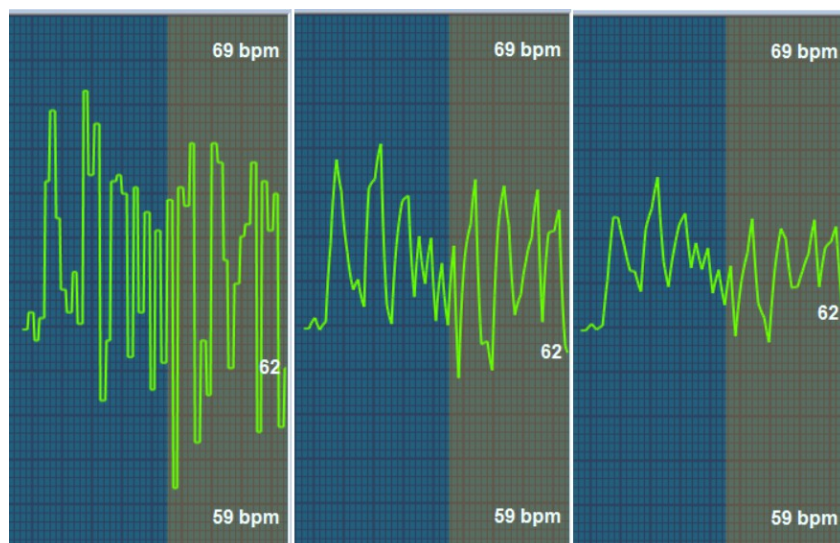
It includes 3 data fields, in which it is possible to set the parameters. Just place the mouse cursor on the relative box, which will be highlighted and then by moving the scroll (wheel) of the mouse up or down, it will be possible to increase or decrease the inside value.

However, always it's possible to directly write the values using the keyboard.

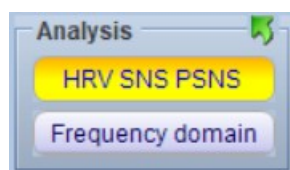
Max BPM sets a default maximum frequency value in the 2 graphics windows

Min BPM sets a default minimum frequency value in the 2 graphics windows

Smoothing. Allows you to smooth the wave crest factor in the bottom graphics window



The here attached image, highlights this effect, with "smoothing" respectively at 0 (zero), at 5 and at 10. The two set values of BPM min are also visible. (in this case 59 bpm) and BPM max. (in this case 69 bpm). The band highlighted on the right, indicates graphically the used ECG speed value, here set at 10 mm/sec. Setting this value to 25, the field narrows and even more to 50.

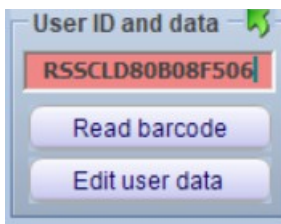


Analysis.

In this window we have two keys that open, when activated and therefore highlighted in yellow as in the example, two dialog boxes.

The first: **HRV SNS PSNS**, also has three sub-levels for as many graphical representations of data.

The second: **Frequency domain**, includes two levels which are analyses: *Fast Hartley Transform* and respectively, one in the frequency domain and the other one in the time (period) domain. We will describe later the detailed operation of these 5 functions which are the ones that include all the functional data of the HRV analysis.



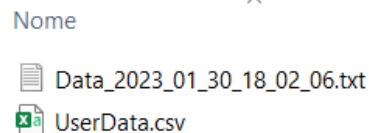
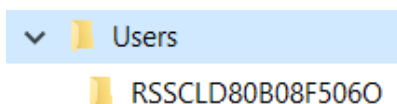
User ID and data.

Here we discover a window and two buttons, respectively: **Read barcodes** and **Edit user data**. In the dialogue window we can manually enter the tax code of the person undergoing analysis, using a normal pc keyboard.



The code will automatically be checked and if correct it will disappear the evidence in red that is present until the entered data is completed, otherwise it will remain in red to indicate an invalid code.

When you finally save the track with the key: **Save data**, a folder will automatically be created under: **Users**, with the same format as the tax code and inside we will also find a data file **".csv"** which contains personal data which if not yet filled in, will obviously be incomplete.



Edit user data. It allows through the Windows where we can enter

Nome	,	you	to	open,
Cognome	,	notepad,	a	page
Cellulare	,	personal data.		
Fisso	,			
Mail	,			

UserData.csv - Blocco note di Windows

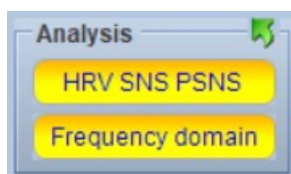
File	Modifica	Formato	Visualizza	?
Nome	,	Rossi		
Cognome	,	Caledonio		
Cellulare	,	333 33 333 333		
Fisso	,	000 111111		
Mail	,	rsclld@xmil.net		

If we mistakenly modify the header data before the comma, when we close the application with: **OK to save**, automatically the document will reopen, underlining the error, restoring the incorrect line to the original format and indicating the mistake in a below line. Once corrected, we will be able to save the file which will now be "cleaned", correctly recognized and saved as: **"UserData.csv"**.

Nome	, Rossi
Corxxxx	Caledonio
Cellulare	, 333 33 333 333
Fisso	, 000 111111
Mail	, rscld@xmil.net

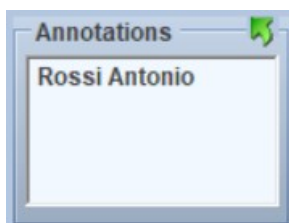
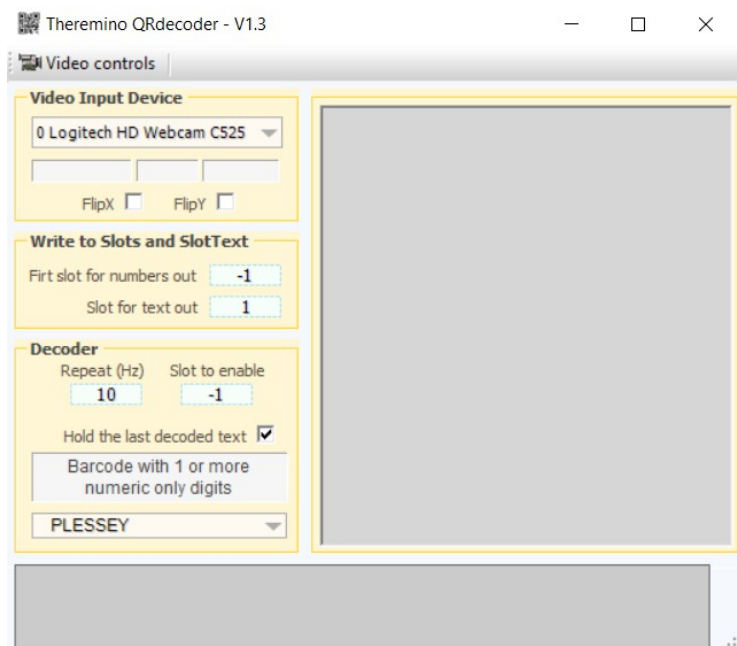
Nome	, Rossi
Cognome	,
Cellulare	, 333 33 333 333
Fisso	, 000 111111
Mail	, rscld@xmil.net

ERRORS
-----Corxxxx Caledonio



Read barcodes. By enabling this function, we will open the application: **"ThereminoQR decoder"**, which through any webcam to be selected in the dialogue window into the application, will allow us to scan documents and cards also among various BARCODE formats.

In our case, for example, it is very useful to scan the health card (this must normally be done with the code: PLESSEY), which can be selected in the dialogue bar at the bottom left and which will automatically insert the tax code in the appropriate box, without having to enter it manually .



Annotations.

It is a simple text field, where we can insert short annotations that will be stored and recalled every time you go to load the previously saved file.

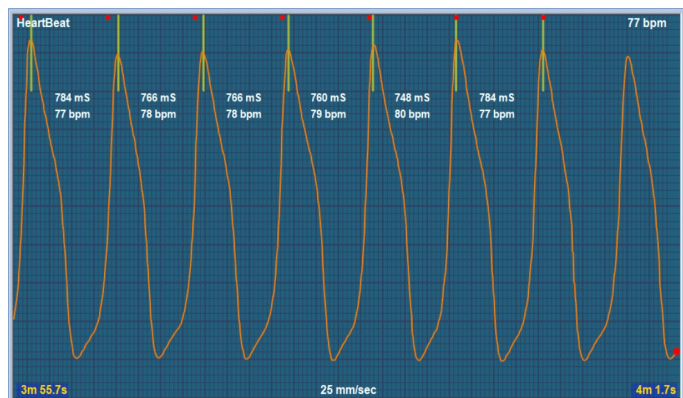
Starting the program

When we start the program, as we said, launches with the executable: **Theremino_ECG.exe**, we will have the screen relating to the last analysis carried out or simple empty, if it is the first time.

If we load a trace from an ECG equipment, we will see pulses with this shape.

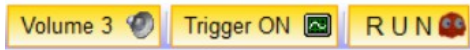


In case the trace comes from an OCG, i.e. from a sensor that detects blood pressure, we will have a wave similar to this on the right.



The OCG signals are processed through special low-pass and high-pass software filters, in order to eliminate disturbances as much as possible and keep the "clean" peaks, so as to obtain maximum precision in the measurement of the RR time which is essential for HRV analysis .

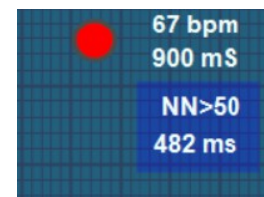
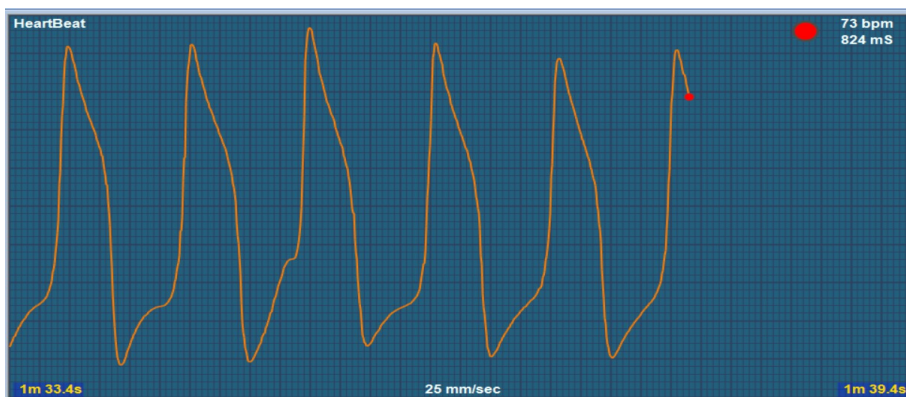
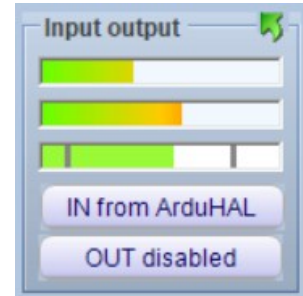
Start recording



By clicking on the button **RUN**, the analysis starts.

If you RUN when "**In from file**" is active, then the heart-beats come from the sample file or from a user file that was preloaded in the folder **Examples** or from **Users**.

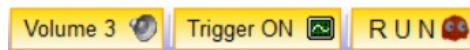
If we want to read the heart-beats with a finger reader, we will keep the button set with "**In from ArduHAL**" or with "**In from HAL**"



During operation beyond the waveform, we have at the top right, the value of the instantaneous beat in bpm and milliseconds and whenever a beat interval exceeds 50 milliseconds, this is displayed in highlighted color, as in the image.

At the bottom right and left, the analysis times are shown, while in the center at the bottom, the speed in mm/sec.

Near the RUN key, we find the button that adjusts the output volume of the BIP and alarm and the **TRIGGER**.



When this is activated, the image will shift to the left with each beat interval and will be visually "still". Only in this case will we have an image like the one above and with only the basic indications available in the window at the top right.

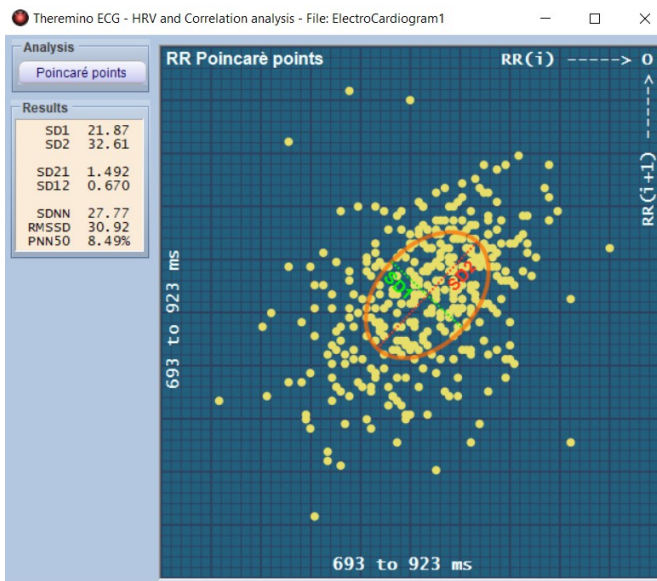
If we disable the "**trigger**", the track will move continuously with a speed proportional to the choice made using the button: "**ECG speed**" and all the individual information, will be indicated beat by beat and will scroll together with them.

Instead, the lower window, indicates the total amount of the tachogram with progress at 1 mm per second. The data at the top and bottom right, establish respectively the bpm min and max and as we have explained before, they can be changed in the appropriate windows in order to center the layout as you prefer.

Pressing the RUN button, the system takes a few seconds for signal stabilization before recording and viewing begins.

HRV analysis SNS PSNS

Under **Analysis**, the button **HRV SNS PSNS**, opens a dialog where we have three possible types of analytical reports. The first one, like example, graphically represents all the RR intervals through a **Poincaré diagram**.

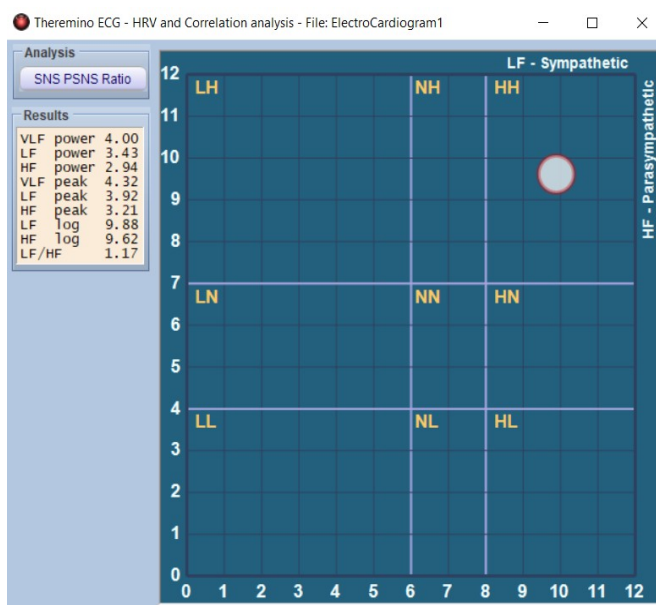


The Poincaré diagram is a scattergram which is constructed by plotting each RR interval against the previous one.

This diagram, can be analyzed quantitatively by fitting an ellipse to the plotted shape. The center of the ellipse is determined by the mean RR interval. SD1 is the standard deviation of the Poincaré graph perpendicular to the identity line, while SD2 is the standard deviation of the graph, along the identity line.

The most significant values we have identified are shown in the dialogue box on the left side and they are precisely SD1, SD2; the SD2/SD1 and SD1/SD2

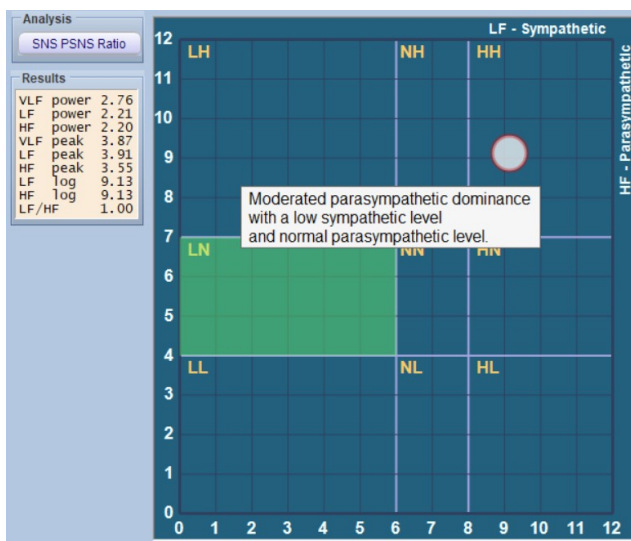
ratio. Then we have the standard deviation SDNN, the root mean square RMSDD and the percentage of intervals greater than 50 milliseconds about global analysis. These data, suitably treated by specialist doctors, can provide a significant contribution to the study of diseases of the cardiovascular system, diabetes, kidney failure, etc.



The **second window**, returns a graph that we have called: **SNS PSNS Ratio** and shows the relationship between the Sympathetic and Parasympathetic Nervous System.

The normal rhythm of the heart is controlled by membrane processes of the cardiac sinoatrial (SA) node, which are modulated by innervation from both the sympathetic and parasympathetic divisions of the autonomic nervous system. Acetylcholine, released from the postganglionic parasympathetic terminals on the SA node, slows down the rate of depolarization and discharge by binding to muscarinic cholinergic receptors.

So, the heart rate decreases consecutively to parasympathetic impulses. Conversely, noradrenaline is released from sympathetic terminals on the SA node and accelerates the heart rate. In addition to these classic neurotransmitter actions, the chronotropic state of the heart can be modulated by a variety of neuropeptides, such as neuropeptide Y, which appear to colocalize with conventional neurotransmitters in the autonomic terminals..



In this analysis window, divided into nine boxes, a mobile dot will indicate the various states of balance between the sympathetic and parasympathetic systems.

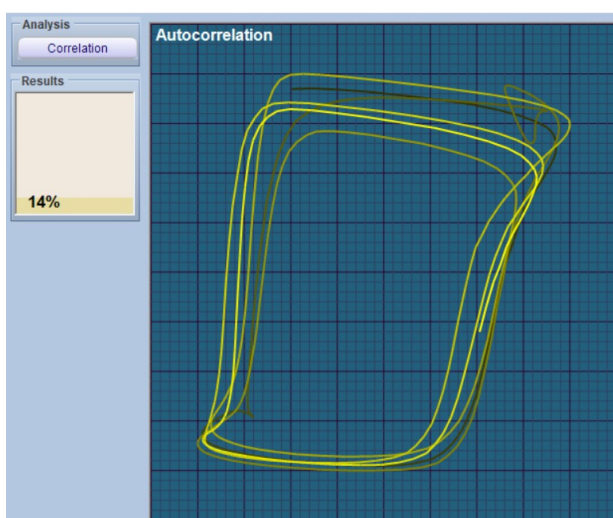
This analysis is performed by calculating the ratio between HF and LF. LF waves are included between 0.03 Hz and 0.15 Hz and they are significant of the sympathetic system, while the HF range from 0.15 to 0.4 Hz are indicative of the Parasympathetic.

We also have VLF waves, lower than 0.03 Hz, but they would require you to set analyzes lasting much longer than 5 minutes, so it makes no sense to consider them in HRV.

This type of analytic approach is mainly used in psychology and holistic medicine.

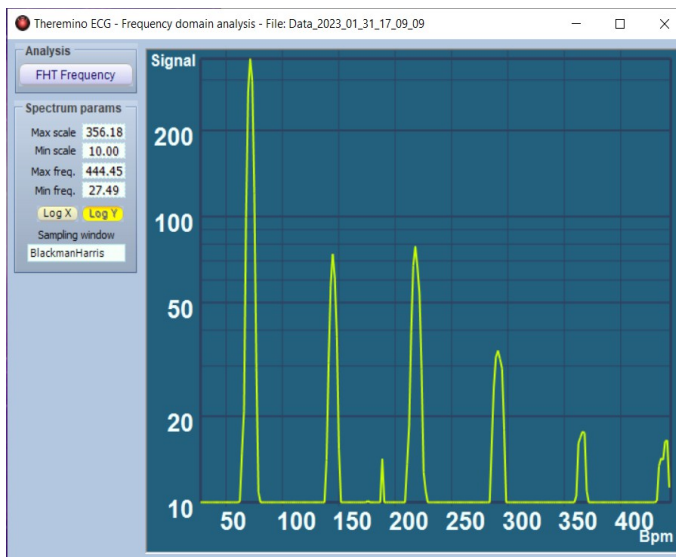
The dialog box on the left side, shows the numerical values relating to the Power and the peak values of both the LF and the HF, as well as the value of the \log_{10} (used for computation) and the LF/HF ratio.

By clicking with the left mouse button on each of the nine quadrants, a dialogue window will open which briefly describes the state of balance between sympathetic and parasympathetic, relative to the entire analysis. If you look at this analysis from the beginning of a new *tachogram*, you will notice a lot of variability, due to the lack of data, which will gradually stabilize and at the end of the 5 minutes it will generally be quite fixed.



The **third window**, graphically represents, the **correlation** of the percentage trend of the various RR intervals relative to the trace in the main upper window. If we set the tracing to 10mm/sec. we will see many more lines because inside the window there are about 25 waves, while with 25 mm/sec. we will see less, since we have about 10 waves and with 50 mm/sec. even less, because it refers only to 5 waves. The image graph on the left, represents a typical trend at 25 mm/sec.

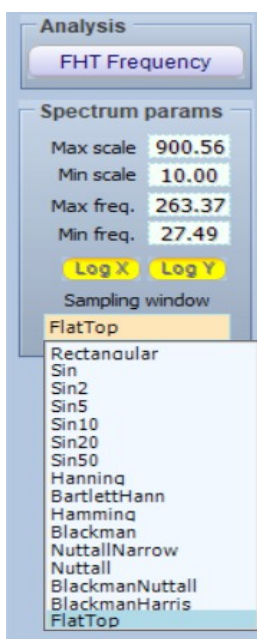
FHT spectral analysis



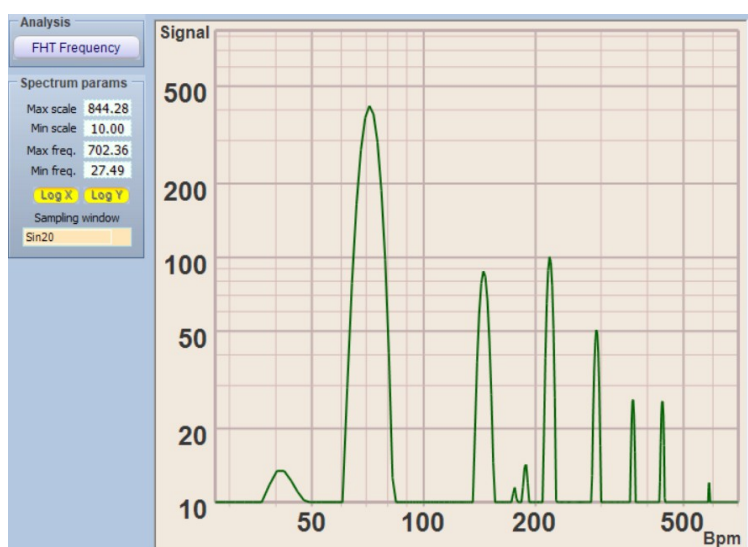
Always under **Analysis**, we find a second key: **Frequency domain**, which allows you to enter two different environments. The first: **FHT Frequency**, graphically elaborates the signal according to the Hartley transform (FHT).

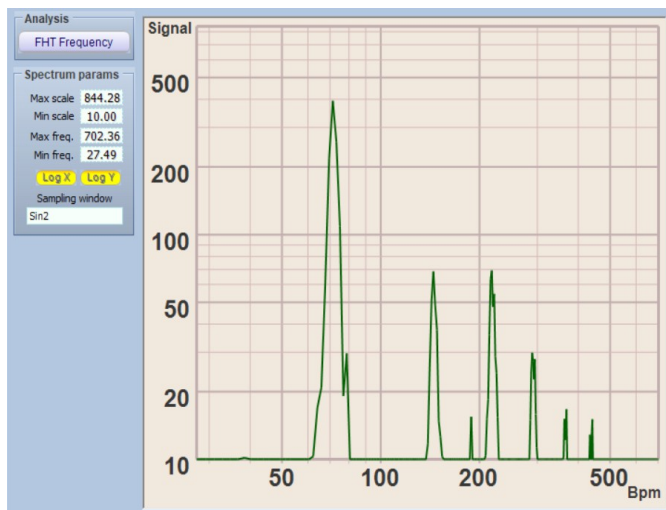
In the analysis of the frequency spectra that is the harmonics of the signals, FFT is almost always used i.e. *Fast Fourier transform*, but in this case we preferred to use the Hartley transform, which is an integral transform closely related to the Fourier transform.

The Hartley Transform, presents the advantages to transform real functions by real functions, instead of requiring use of complex numbers and moreover, to be properly reverse to herself (*involution*). Therefore from a computational point of view it is lighter, occupying less memory space and processor calculation capacity.



In the left side menu we find the values of the scales that can be manually entered from the keyboard or by positioning the mouse cursor over the box and using the scroll back and forth to increase or decrease the values. The same can be done by going directly with the pointer on the ordinate or on the abscissa and always with the scroll you get the same function.





Then we have two keys Log X and Log Y which transform the scales from linear to logarithmic.

Finally, at the bottom, under **Sampling window**, by clicking on the dialogue window, a curtain opens with countless choices on the type of calculation algorithm among the various and most common scales used.

Here we have also added the calculation functions *sin*; *sin2*; up to *sin100*, which stand for sine, sine squared, and up to sine at *umpteenth* power.

These functions allow us, starting from the function: *sin*, where the peaks are very narrow, a progressive softening on the other scales. In the image above, you can see the difference between the *sin2* scale, very similar to *Hanning* to *Battler-Hann* and *sin20* (previous page), where the peaks are much softer with the presence of a peak at 30 Hz.

By clicking again on the top button (under analysis) we will have access to: **FHT Periodogram**, a window that represents the same data as in the previous analysis, but in the time domain, rather than frequencies.



The controls for setting the scales are the same as in the previous window.

Here we have defined with different colors of evidence, the two main spectrum bands: LF and HF.

In order to achieve greater versatility, we recommend keeping set the Min. freq. value. at 0.03 and the Max. Freq. to 0.6.

These graphically represented values, are the same stored and used to calculate the balance of the sympathetic / parasympathetic system and the displayed curve already gives us an important visual indication of the trend of the LF and HF Powers.

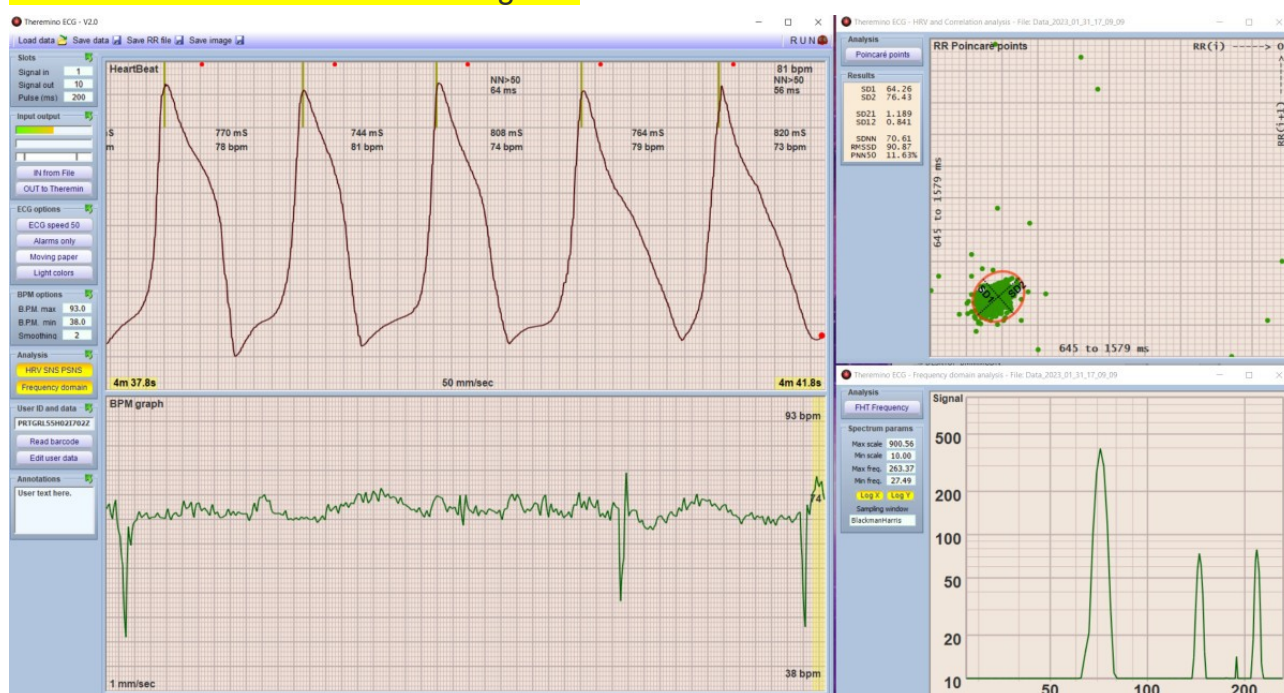
Adjustments and artifacts

Removing an artifact (noise) is probably the most important step of the signal processing stage and mandatory to calculate HRV characteristics. Although all beat-to-beat data pass through special software filters, the possibility that disturbances are generated and recorded, due to breathing and simple movement of the patient, especially during investigation by OCG, but also in ECG, is real and important, because it can generate anomalies that can influence the result of the analysis. Even a single artifact in a 5 minute window can have significant consequences in terms of derived HRV characteristics. We assume there are three possible fundamentally relevant actions where targeted actions needed.

1. Remove extreme values(*range filter*), i.e. anything that does not translate into an instantaneous heart rate for example between 20 and 200 bpm.
2. Suppress beat-to-beat anomalies. This means removing differences that, for example, are greater than X%, as it would not be physiologically possible, since "X" would have to change based on the person's actual baseline HRV and assumed common thresholds between 20 and 25% could correct excessively. Overcorrection may be a negligible problem for non-athletes, but should be considered in a population with particularly high HRV values.
3. Eliminate the remaining outliers. After the previous steps, we may still find some outliers, especially if we were less strict with the anomaly filter (for example with 50-70% for athletes, we may have more artifacts to remove).

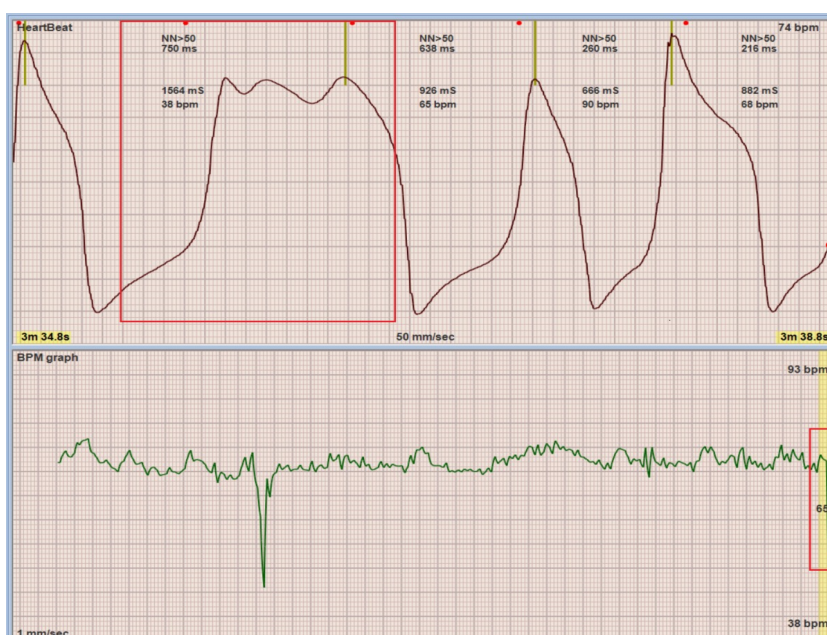
At the end of a recording analysis session, where the data can be stored in a dedicated file, as we have previously described, the doctor and the professional who, in his opinion, deems it necessary to eliminate some potentially harmful artifacts, will be able to do so with some simple, easy and powerful interactive tools.

The screenshot above illustrates a typical OCG with some possible artifacts that can be processed. The interactive windows between them, are the two of the main diagram and the window with the "Poincaré" diagram.



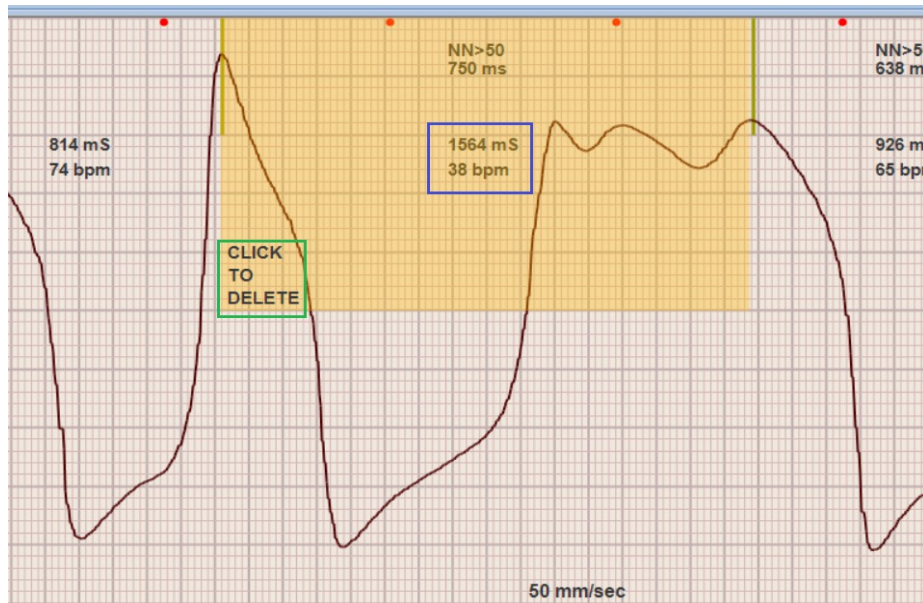
In the two main windows, we can carry out the same operations, but while in the upper window we have greater visibility of the details, the lower one offers reading over a much wider range and which, depending on the width of the window, can even include an entire layout of 5 minutes.

Going on the graph(*any field as long as it is outside the written data*) with the mouse and holding down the left "click" key, we can move the track to the right and to the left to position on an area at will. Our advice is to use, as much as possible, the bottom window, which offers us a path that roughly encompasses the entire analysis, and then move to the upper one to refine the positioning.



By dragging a possible artifact inside the band highlighted on the right, as in the example, we can see the anomalous shape appear in the window above.

To eliminate a zone, click with the mouse pointer positioning it approximately on the writing (in this example: 1564 ms and 38 bpm).



this will open an area highlighting that stretch of recording and by clicking on: **CLICK TO DELETE**, the highlighted artifact stroke, will be deleted and the path automatically trimmed.

By holding down the CTRL key, in the same way, we can select multiple areas and equally to delete them all.

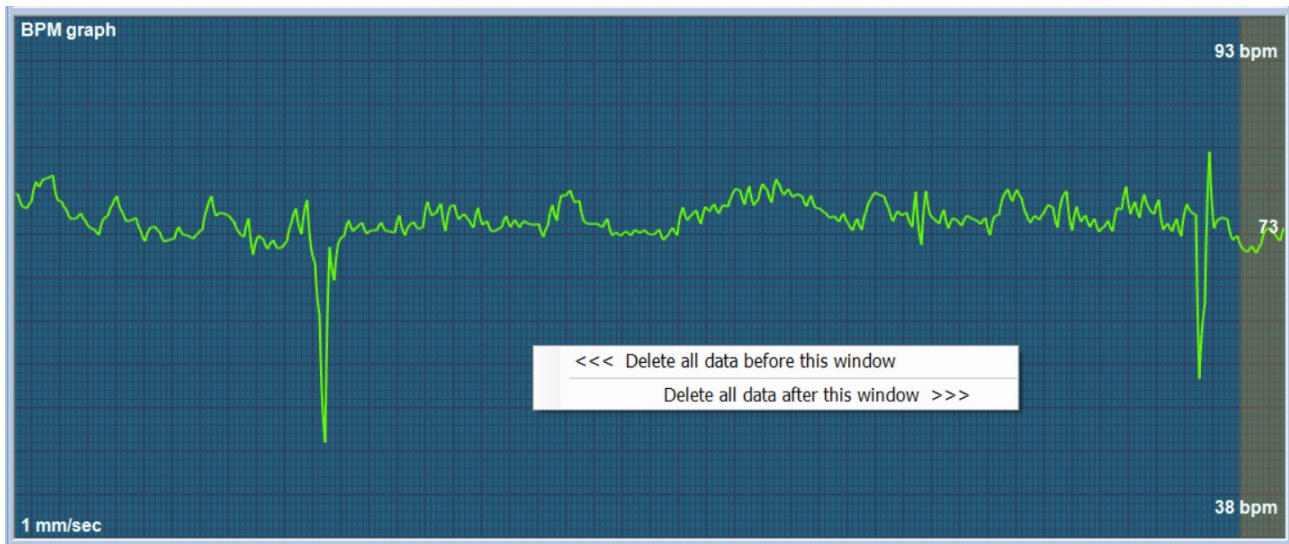


With these practical functions, we can practically eliminate the disturbances we have talked about, but we still have another very versatile tool that we will see shortly.

To eliminate the head and tail of the diagram, we can make use of a function that opens by clicking on the windows with the right mouse button and which translates into the appearance of a dialog box:

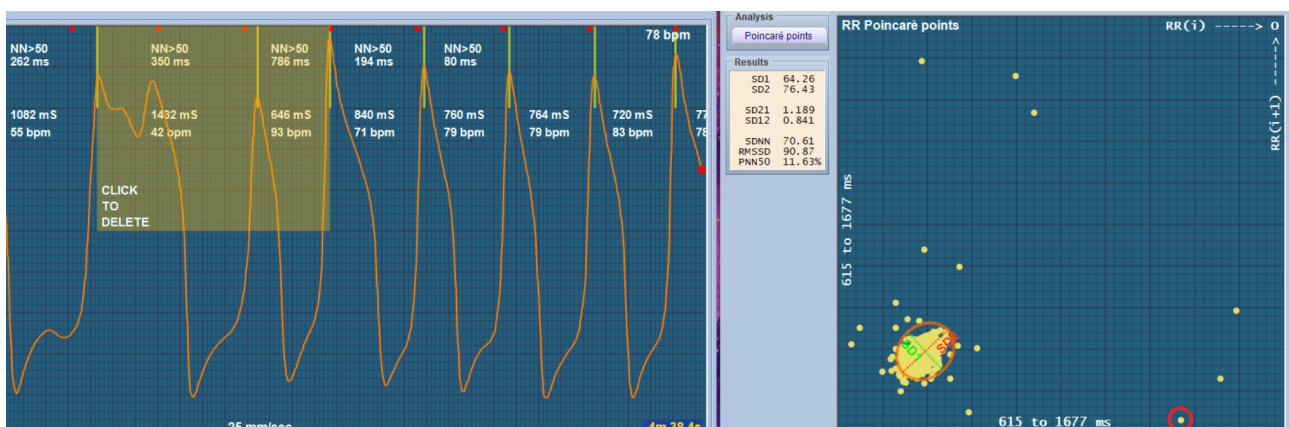
<<< Delete all data before this window / Delete all data after this window >>>

By clicking on the respective areas, it will in fact be possible to delete everything that is there (*invisible*) to the left or right of the graphics window, i.e.: "*before or after*". The same operation can also be performed in the upper graphic window which allows greater precision. But let's be careful don't delete too much.

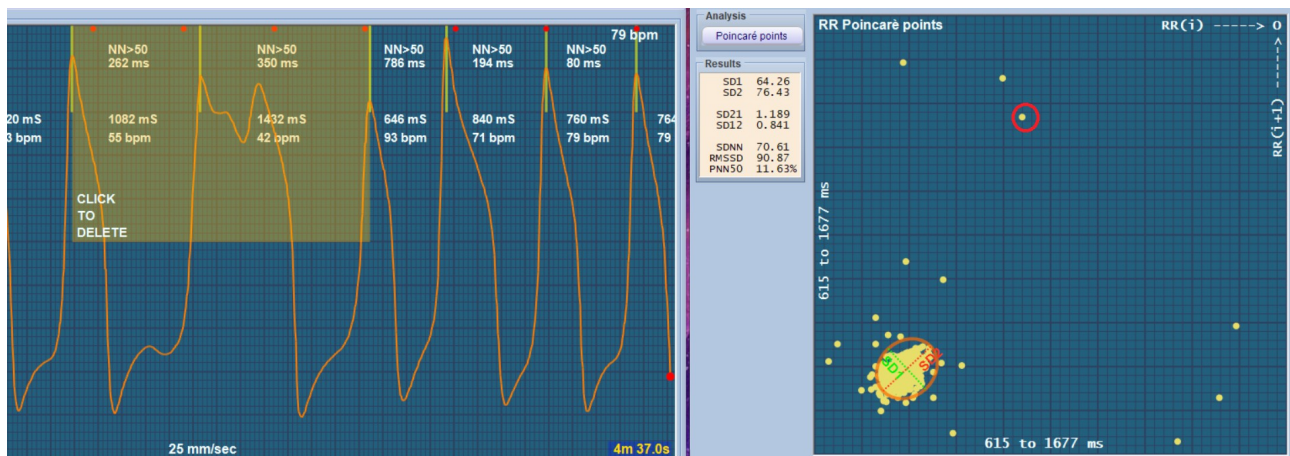


Finally, to facilitate the detection and suppression of any unwanted disturbances, as mentioned above, we can also work on the Poincaré window.

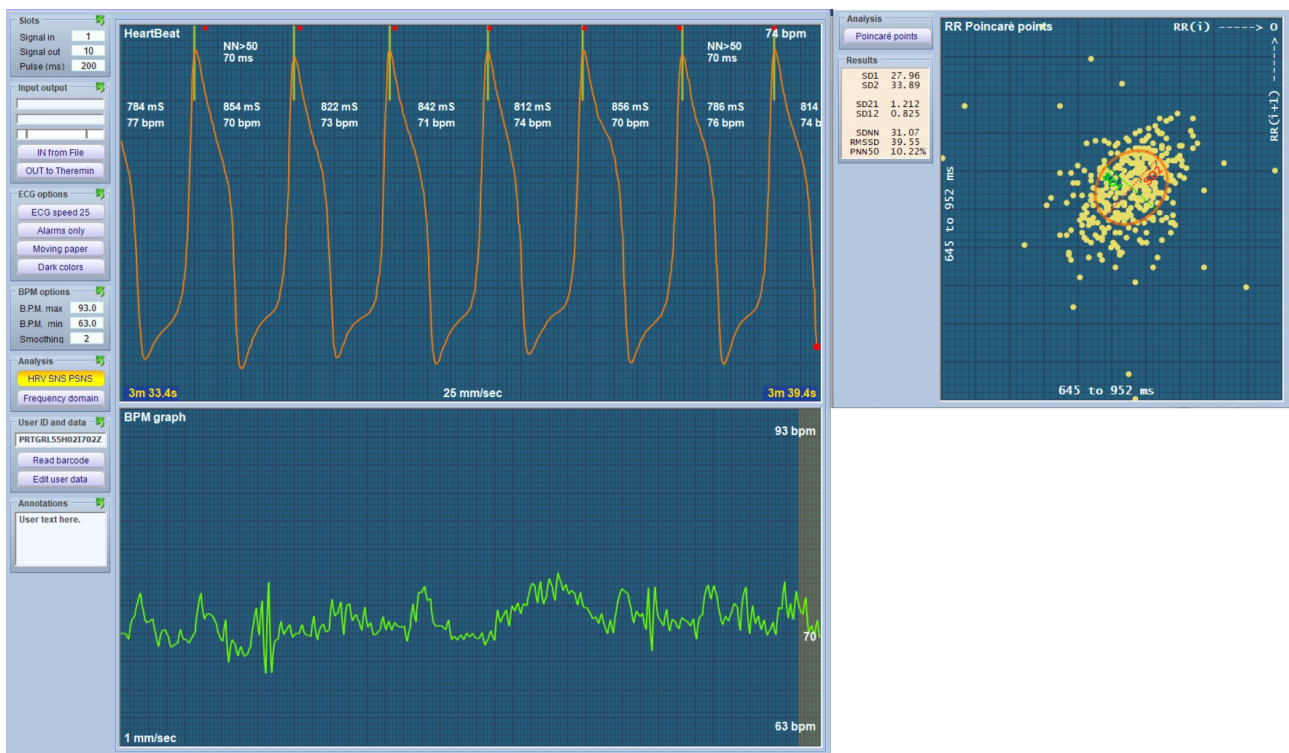
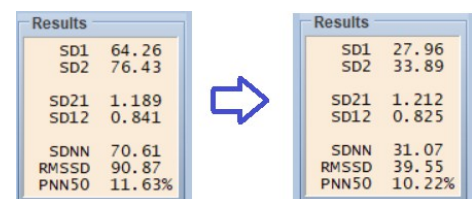
By double-clicking the left mouse button on one of the points which are well out of range and which we believe we need to analyze, an area highlighted in the upper main graph will open, indicating the affected area, as in the example shown below.



We point out that it is correct that the area always includes two values, since it is a consequence of the calculation of the interval $RR(i)$ and $RR(i+1)$.



For example, in this case the point highlighted in red includes the intervals: **1082mS and 1432mS**, while the next point positioned at the bottom right, includes the intervals: **1432mS and 646mS**.



We can immediately notice in the data windows, deleting the various possible artifacts (*most peripheral points*), we will see a track without the previously highlighted peaks, but with very different data vs. before.

Therefore these "manipulations" must be performed with skill by qualified personnel and above all capable of distinguishing the real artifacts from the real cardiac anomalies to be considered.

Technical notes

Sensors

Basically two types of sensors can be used:

OCG(Optical Cardio Graphy) *(note 1)* - The [optical sensors](#) they are convenient for frequent testing at home and in any doctor's office, allowing to locate arrhythmias when they occur. The sensor and the special amplifier designed by us produce an almost constant signal even when the patient's characteristics vary greatly (blood pressure, sensor positioning, thickness and hue of the epidermis). Sensors not specially calibrated, they may present disturbances and inconstant sensitivity. Subjects with low blood pressure, usually produce a weak and disturbed signal that often makes it difficult if not impossible to control arrhythmias

ECG(Electro Cardio Graph)- The classics [differential amplifiers for ECG](#) which are more inconvenient to use *(note 2)*. These sensors require special electrodes with conductive paste and skin preparation with alcohol and cotton. The preamplifier requires special components so it cannot be built by yourself. And while paying all these attentions, the system is very sensitive to movements, so you have to remain motionless so as not to disturb the recordings.

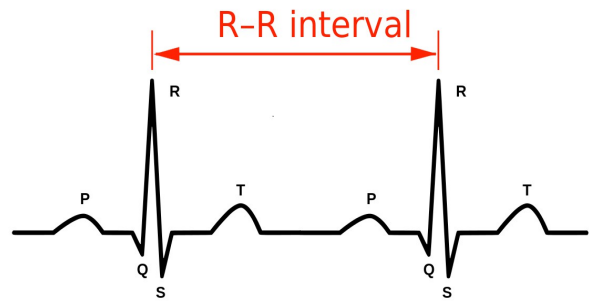
(Note 1) The exact name for optical sensing would be "photoplethysmography" but it's complex and hard to remember. Since optical instead of electrical variations are detected, the equivalent of "Electro" is not "PhotoPlethysmo" but "Optical" and therefore we will call it: OCG.

(Note 2) The advantage of ECG sensors compared to optical ones is to be able detect electrical activity of the heart but to achieve it, an alone derivation is not enough and therefore must be used twelve. Ten electrodes are therefore needed, six positioned on the chest and four on the legs and arms. The preparation and subsequent removal, requires some minutes, cleaning and application of conductive gel and is therefore inconvenient and not particularly useful for HRV investigations..

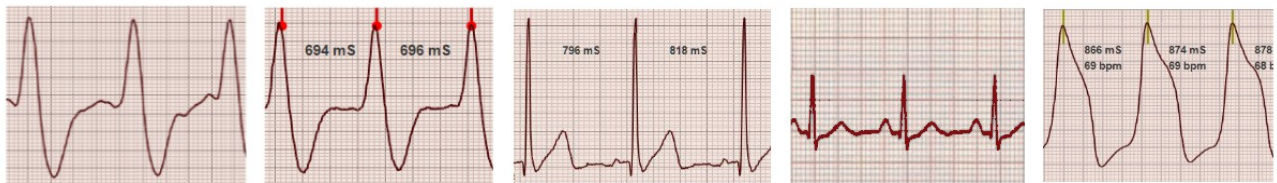
Shape of the ECG & OCG signals

This application can also be used to store and explore classic ECG data. But for HRV and arrhythmias, the only significant data is the (R-R) elapsed time between pulses.

In this image we can see an example of ECG (first derivation) with the classic P, Q, R, S and T waves.



Pulse shape depends on measurement filters (in OCGs) and the lead used (in ECGs) but for HRV analysis has no significance.



The only important data is the time in milliseconds (called R-R) which, to obtain maximum precision, is measured between two successive R peaks of the PQRST complex.

Detecting arrhythmias



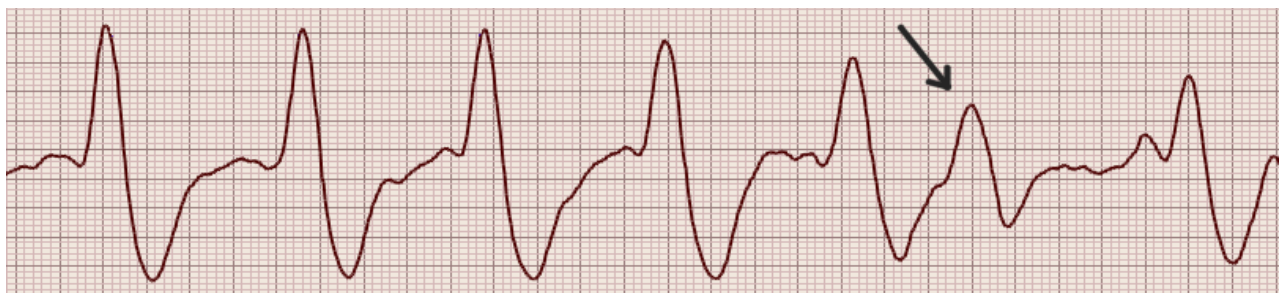
This application facilitates the analysis of arrhythmias but doesn't detect them and no sound is emitted unless the arrhythmia involve the frequency outside the set BPM limits.

To determine if an event is a true arrhythmia experience is required. On the net there are many example graphs with various types of arrhythmias.

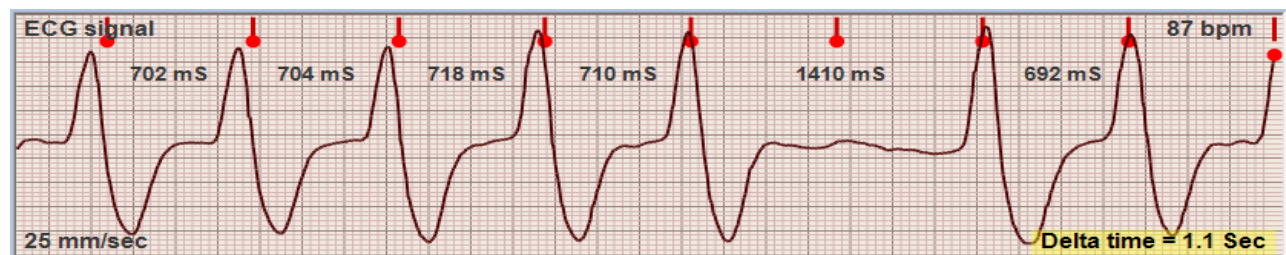
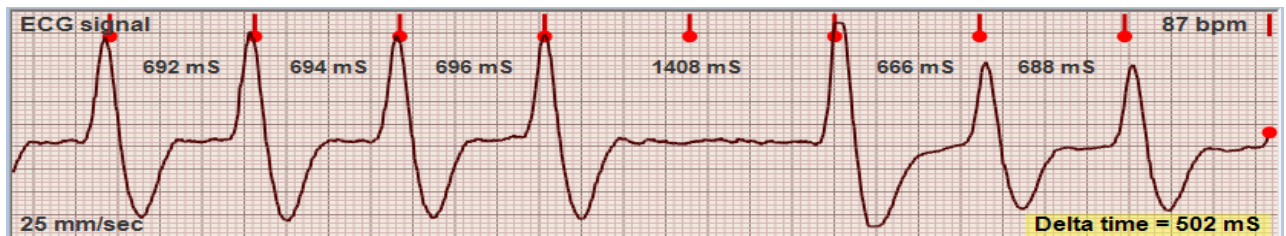
The most common form of arrhythmia (and the least worrying) is early contractions. In practice, a contraction arrives after only two squares (approximately) instead of the usual four (approximately). *We are referring to the classic setting of 25 mm/sec.* And this event is then followed by a longer pause than normal.

Arrhythmia examples

The next two images shows examples of early contractions, the first one, with classic ECG sensors and the second one with our optical sensor. Pay attention that the optical sensor could show information that's not visible with the electrical signal. In this case we see that the pumped flow was less (the peak indicated by the arrow is lower than the others) because the heart didn't have enough time to fill up completely.



The following two images show "skipped" beats, about that we don't know the exact technical term.



On the net many people claim to have the feeling of skipping a beat every now and then. And they are often told that it is just a sensation and that they are actually early contractions. But these graphs highlight that "skipped" beats may really appear. Probably the exact medical term, could be "Atrioventricular block".