

# Altera – Heart Rate Variability Analysis Software for Small Animal Models

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**Abstract**—Altera is an advanced and easy-to-use program for heart rate variability (HRV) analysis. HRV research has been gradually gaining momentum due to increasing interest in the field alongside relevant technological advances. Key features of the program are the R-peak detection, artifact correction via manual user input, and dynamic presets for different types of subjects. Compared to other programs that compute human HRV data, Altera can be effective when analyzing small animal data such as rats and mice.

**Keywords** — Heart rate variability; software; algorithm; cardiovascular; autonomic nervous system; small animal model

## I. INTRODUCTION

Heart rate variability (HRV) is the variation in beat-to-beat intervals. Along with blood pressure (BP) and regular heart rate (HR), HRV is increasingly acknowledged as an evaluative tool for autonomic nervous system (ANS) function and cardiovascular state [1]. For example, prior studies have shown myocardial infarction survivors lack variability and have higher chances of suffering fatal heart attacks [2]. Overall, this variance demonstrates the heart’s ability to adapt to different environments and states, as well as the balance between the different branches that compose the ANS.

The introduction of computer technologies during the 1980s gave way for new signal processing techniques for electrocardiogram (ECG) recordings and analysis algorithms. Today, HRV parameters are used in conjunction with more established measures of HR for evaluative purposes. However, popular HRV analysis programs only provide algorithms optimized for human data, making them unsuitable or at the very least impractical for work with small animal model data (e.g. rats, mice). Thus, HRV research conducted on small animal models must either rely on custom algorithms and analysis scripts or spend hours preprocessing data.

To make HRV research more accessible for experiments on non-human models, we developed Altera HRV. Altera provides time and frequency domain analysis functions and a user-friendly GUI, allowing researchers from all backgrounds to easily extract standard HRV measures.

## II. SOFTWARE AND ANALYSIS DESCRIPTION

The next section is devoted to describing the functionalities and the general flow of the program.

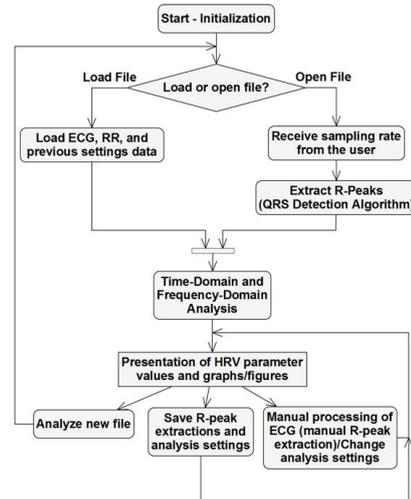


Fig. 1. Altera program flowchart.

### A. Data Input and Processing

As of version 1.0, the program takes raw ECG readings in ‘.mat’ format. The user is then prompted to indicate the sampling frequency of the recording. The program then automatically detects the peaks and generates the RR interval series. Users interact with Altera by way of a graphical user interface (GUI). Version 1.0 was built with Matlab’s GUI development tool and application compiler. The GUI is divided into three sections: 1) The RR interval series section; 2) Analysis options section; and 3) The results section. In the analysis options section, the user can set the time window for HRV analysis. These sections are noted in Figure 2.

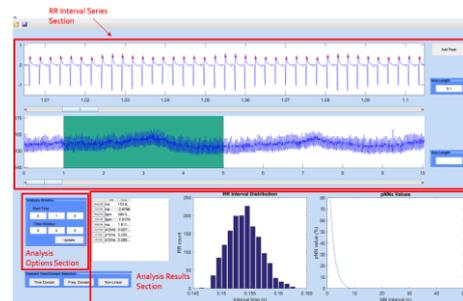


Fig. 2. Altera UI divided into the three main sections.

## B. Save and Load Options

Altera provides session saving and loading functions that facilitate continuing post-processing work (i.e. adding undetected R-peaks) at later times. Saving a session stores analysis settings and R-peak locations. This is primarily useful for when working with arrhythmia-heavy datasets that may have some hard to detect QRS complexes.

## C. Parameter Analysis

The program provides time and frequency domain analysis methods and presents the results graphs that allow users to gain quick insight into the current data sets. Fig. 3 depicts the analysis figures, while Table 1 lists the parameters obtained from the analysis.

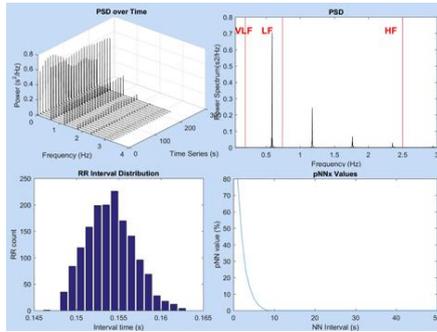


Fig. 3. Altera Sample Parameter Analysis Figures (Top two figures pertain to frequency domain analysis, bottom two figures to time domain analysis).

TABLE I. EXTRACTED HRV PARAMETERS

Parameter	Units	Description
Mean RR	ms	Mean (RR) interval length.
STD RR (SDNN)	ms	Standard deviation of RR
Mean HR	bpm	Mean heart rate.
STD HR	bpm	Standard deviation of HR
RMSSD	ms	Square root of mean squared differences between successive RR intervals.
NNx	Count	Number of successive RR interval pairs that differ by more than x ms.
pNNx	%	NNx (for the corresponding x value) divided by the total number of RR intervals.
VLF, LF, and HF Power	ms <sup>2</sup>	Absolute powers of VLF, LF, and HF frequency bands.
Relative VLF, LF, and HF Power	%	Relative powers of the frequency bands.
LF/HF Ratio	-	Ratio of LF to HF powers.
Total Power	ms <sup>2</sup>	Total spectral power.

## D. QRS Detection Algorithm

Altera automatically extracts the location of R-peaks through a custom QRS detection algorithm based on the Pan-Tompkins algorithm. The data is normalized by subtracting the mean and then dividing it by the absolute maximum value. This is then run through a second order Butterworth filter (2 – 300 Hz) to reduce powerline noise, baseline wander, and other noise components. This is then convoluted with a low pass filter to attenuate frequencies higher than desired. The convoluted samples are squared to accentuate the R-peaks and once again convoluted with the low pass filter. Finally, a

moving average filter is used to clear out double R-peak instances. The signal is then put through a thresholding process; Peaks are deemed as R-peaks only if they are at least 40% the magnitude of the maximum peak in the data set [3]. This thresholding process helps delete possible outliers and discard random peaks in the QRS complex. After the R-peaks are detected, they are interpolated to improve the time resolution of the detection.

## III. RESULTS

We compared analysis results for three synthetic data sets (increasing frequency, decreasing frequency, and alternating patterned frequency). The data sets were created with different combination of sine waves with a fundamental frequency of 6 Hz. This was to account for the bpm of rodent models whose bpm is around 360. The algorithm for generating the synthetic data sets was based on ECG simulator for Matlab [4].

Our test results are shown below with the comparison to a leading HRV analysis software.

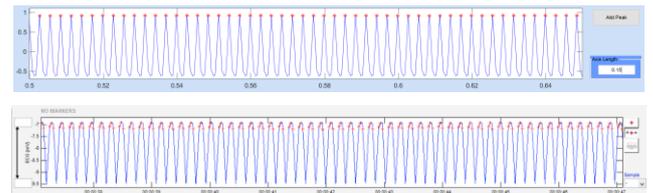


Fig. 4. Comparison of QRS Detection Algorithms, a) synthetic ECG with detected peaks in Altera, b) synthetic ECG with detected peaks in leading HRV software - peak detection algorithm both failed to detect and falsely detected multiple peaks in the data set.

## IV. CONCLUSION

In this paper, we introduced a new HRV analysis tool geared towards research use, with algorithms optimized for small animal model analysis. Through customized preprocessing algorithms, parameter extraction scripts for time and frequency domain analysis, and increased accessibility, Altera presents a complete solution for research labs conducting cardiac research on non-human subjects.

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