Accelerated Pipeline for ECG Examination

Zhor RAMDANE CHERIF[1], Gauthier GIMBERT[1], Julien OSTER[1,2]

[1]Université de Lorraine, Inserm, IADI U1254, F-54000 Nancy, France

[2]CHRU-Nancy, Inserm, Université de Lorraine, CIC 1433, F-54000 Nancy, France

This study presents the development of a software platform for processing and analyzing electrocardiographic (ECG) signals. Existing solutions often lack flexibility for integrating new methods, and are limited in speed and scalability when handling large datasets. To address these limitations, our platform is built on a modular and flexible architecture with high-performance computing optimizations.

The main contributions are: (i) a configurable and parallelizable processing pipeline; (ii) GPU acceleration using CuPy to reduce execution times; and (iii) a dynamic integration mechanism allowing new methods to be added without modifying the core. The platform is organized into independent components covering data import, denoising, detection, classification, and evaluation. The pipeline is modeled to enable asynchronous execution and efficient parallelization. The workflow includes importing data from the signal database, denoising to reduce artifacts, detecting and classifying heartbeats via the QRS complex, and evaluating performance using quantitative metrics as sensitivity, positive detection, F1-score, etc.

To evaluate our platform, ECG signals recorded in an MRI environment from 14 subjects were analyzed. The performance of a simple QRS detector using a fixed threshold (set to four times the mean signal value) was assessed with median filters of different window sizes. The results show that optimal performance for our dataset was obtained with a 10 ms window. Specifically, sensitivity improved by 18%, while the F1-score increased by 0.44.

The results also demonstrate substantial improvements in processing time and the platform ability to efficiently handle large volumes of data. The dataset comprises 6 3-lead sensors and more than 17 minutes of beat-level annotated recordings per subject. Processing time was reduced by 88% when using a GPU architecture compared with a CPU-based implementation. These results confirm that the software provides high-performance, is flexible, and fully adapted for large-scale ECG analysis.

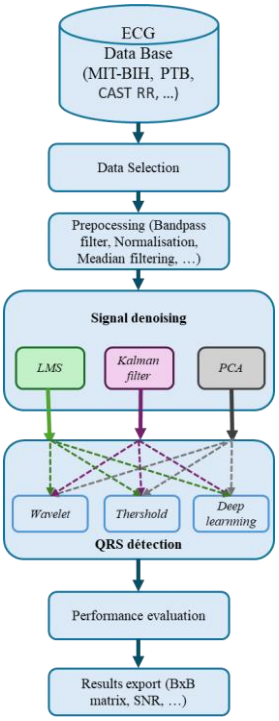

Figure 1:Workflow of the Proposed ECG Processing Pipeline

Filter Size (msec)	SE (%)	PPV	F1-Score
Without filter	64	29	0.40
1	67	33	0.44
5	83	73	0.78
10	82	85	0.83
15	72	86	0.78
20	67	86	0.75

Table 1: The table presents the performance of a simple detector, evaluated by applying a median filter to ECG signals. The results show that filters with windows sizes of 10 and 15 msec provide the best trade-off in terms of sensitivity and precision.