

ECG Signal Data Processing for an Imaging Processing Based Cardiac Mapping System

A Work Experience Paper

by

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1. Summary of Technical Work

The project to which I contributed is an imaging processing based Cardiac Mapping System aiming to: ^[1]

1. Develop and validate the novel 3D algorithm(s) to identify the origin of ventricular arrhythmia based on intracardiac signals recorded during VT to facilitate ablation;
2. Develop and validate novel non-barometric technologies to assess hemodynamic changes during detected cardiac arrhythmia to guide the delivery of ICD therapy.

In this process, CARTO, a 3D Cardiac Mapping System was used to register the pacing sites and the locations of recording electrodes. ^[1]

Also, we recorded the Electrocardiograph (ECG) signal data collected through the electrodes using the Bard Electrophysiology Recording System, then restored, analyzed, and processed the signal using MATLAB.

The recorded data from the Bard System was saved in a proprietary data structure. In each data file, there is the header, which bears the information about how the structured data was stored. For instance, each channel represents the signal received from an electrode, the label of each channel is coded to represent the position of the electrode, the gain of each channel, the sample rate represents the sampling frequency that the signals were acquired, and the total number of the sample, etc. It's very important to understand these prior to parsing the data from the data files.

Before processing the data, first I used MATLAB to read in data from the data file. The data was read in as a matrix, with each channel's data occupying a column. The corresponding headers were read in as another matrix. Then, when plotting the data of each channel, I set the number of data in each column as the domain on the x-axis, and the data as y values. I also extracted the corresponding label of each channel from the header matrix, and passed it in as the title of each graph.

Finally, I processed the ECG signal by adding a low-pass filter to reduce the noise. Using a low-pass filter function provided by MATLAB, I passed the sample rate in the header as the 'fs' parameter, representing the frequency the data was sampled in. Then for 'fpass' parameter, representing the passband frequency of the filter, I used the 'low' frequency in the header, a frequency between 30-100Hz, to filter out all the noise higher than this frequency. To check the quality of the ECG signals and the effects of the processing, I plot all 42 channels of ECG signals on one page using a self-defined function.

As showed in the following flowchart, after ECG data being read in and filtered, the more in-depth signal processing started.

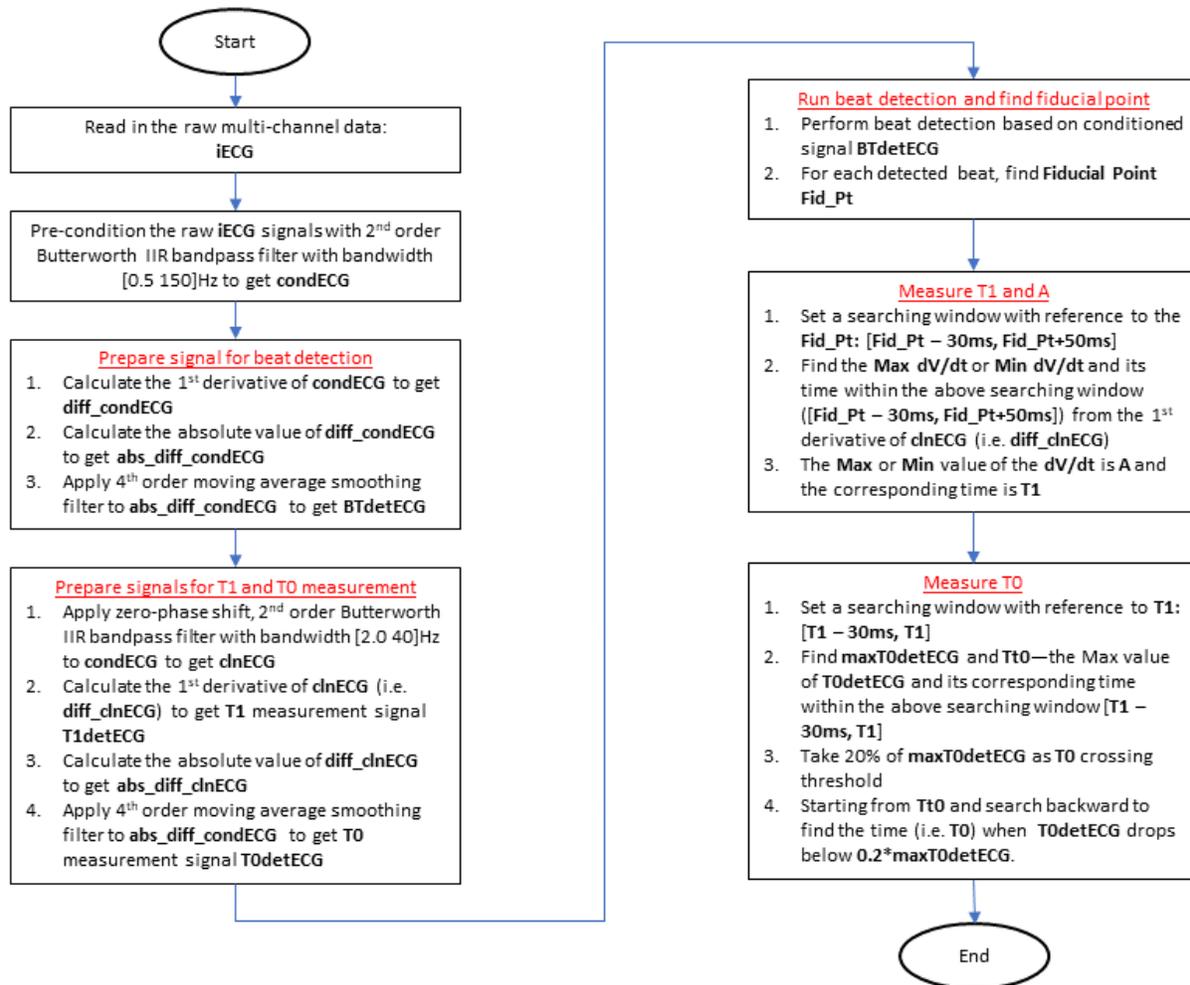


Figure 1. Flowchart of ECG signal processing

In summary, the in-depth signal processing includes: 1) heartbeat detection, 2) T1 and A measurement, and 3) T0 measurement.

Because this is a long-term project, and the internship hasn't ended yet to this date, it can be expected that more interesting and challenging programming tasks are right before us.

2. Your Role on the Project(s)

The team leader is Dr. Cheng, the Electrophysiologist. Dr. Liao, the Software Engineer of the company, is the one taking care of my training and working as a summer intern in computer science and data analysis area.

I'm working on this project as a software technician and data analyst. My major work is to analyze and process the ECG signal collected through the Bard System.

3. Goals and Metrics for Your Work

I was expected to learn MATLAB, and use it as the platform for data analyzing.

I was also expected to attend the experiments and participate in operating the Bard System and CARTO 3-D mapping system.

Besides, I was expected to participate in developing the algorithm for the above-mentioned signal processing tasks, processing data, evaluating results, and improving the algorithm.

My work is evaluated depending on the correctness and readability of the ECG signal I generated.

I report to Dr. Liao, the Software Engineer, weekly and whenever needed through email, about my current work progress and my questions in the process. The progress reports are mostly written in the email, but sometimes orally through in-person meetings or video chat.

4. Progress of Your Work

I successfully accomplished the goals expected of me.

Firstly, I learned MATLAB thoroughly, used the software to process the ECG data collected from the Bard System, and used a low-pass filter to reduce the noise in the signals.

Secondly, I attended the two animal studies and participated in the operating of the Bard System and the CARTO System in data collection.

Finally, I conducted preliminary signal processing with the algorithm I had programmed.

All in all, my accomplishments met the goals initially set.

5. Lessons Learned

The lesson I learned is that, always learn about the background knowledge before you start the program. At first, I didn't know about the operating principle of the Bard System or the structure of the data file, so I found parsing the data very confusing. But after I learned about the Bard System's working principle and the data structure it generates, I had a breakthrough point.

Also, I learned that going into the industry means that you need to learn quicker and better. I assumed that all the knowledge I learned from school would be enough for me to handle the project, but it turns out that I would need to learn MATLAB from scratch in a short time and immediately apply it to real problems. Now I understand that it would be normal in the real work environment. Besides, it is different from taking classes in college, where you learn what you need from the professor. In the real working environment, you are going through a process of solving the problems by researching what you need.

Due to the COVID-19 crisis this year, most of the communications went online, and team working is not very easy in this situation. However, we still communicated a lot, it made me realize how important it is to work together as a team and learn from each other.

6. Resources and Tools Used

We used the Bard System. The Bard Electrophysiology Recording System is used to record the intracardiac ECG signals through the catheters placed inside the heart. ^[2]

Also, the CARTO 3-D mapping system was used. It is designed to acquire, analyze, and display electroanatomical maps of the human heart and provides a real-time display of catheter position superimposed on the 3D cardiac maps constructed. ^[3]

I also used MATLAB to process the signals, as described in part 1.

Besides, I worked with Dr. Liao on operating the equipment, processing signals, and developing the algorithm. In addition, I also participated in the animal study planning, study protocol drafting, and study report writing.

7. Training Received

I learned MATLAB by reading through the user manual of MATLAB, watching video courses online about MATLAB basic operations, and using the official website as a reference in programming.

I also learned signal processing by watching videos of a signal processing course, and the use of filters in MATLAB.

Besides, Dr. Liao taught me about the operating principle of the Bard System, the requirements in restoring and analyzing data, and how we should develop the algorithm for the analysis of data.

8. TAMU Preparation

My education at TAMU was very helpful to my job.

First of all, although I'm not using C++ language in the summer, the knowledge I acquired from CSCE 121 and 221, in building the structure of a program and algorithms are especially helpful. Also, the experience of CSCE 314 helped me to learn and apply a new language quickly.

Secondly, the math courses I did in TAMU, especially linear algebra, were helpful in the learning and using of MATLAB. Now I comprehended how useful and necessary math is in the field of computer science.

I believe that we could use more introduction about the application of computer science in other fields, such as the medical field, data analyzing and statistic field, etc.

9. References

[1]: Cheng, Jie. "NON-CLINICAL LABORATORY STUDY PROTOCOL." CHELAK Medical Solution INC., 2018.

[2]: *IntellaNav ST Ablation Catheter User Manual*, Boston Scientific, 2018, www.bostonscientific.com/content/dam/Manuals/us/current-rev-en/50476382-01B_IntellaNav_ST_DFU_en-USA_S.pdf.

[3]: DeSena, H. C., and B. C. Blaxall. "CARTO." *CARTO - an Overview | ScienceDirect Topics*, Cardioskeletal Myopathies in Children and Young Adults, 2017, 2017, www.sciencedirect.com/topics/nursing-and-health-professions/carto.