EE798 Remote Image Formation Theory Project

Analysis and Reimplementation of

Improving the spatial solution of electrocardiographic imaging: A new regularization parameter choice technique for the Tikhonov method

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I. INTRODUCTION

Electrocardiographic Imaging (ECGI) is a noninvasive method for reconstructing the epicardial potentials from the body surface potential mapping that can diagnose diseases such as tachycardia [1] and atrial fibrillation [2], [3]. The number of measurement non-invasively taken from the torso surface, however, is less than the number of reconstructed cardiac sources that provides satisfactory spatial resolution for the diagnosis. Due to the inherent ill-posedness of this underdetermined problem, utilization of regularization is mandatory to achieve physiologically suitable solutions [4]. Tikhonov Regularization is a widely used regularization technique in ECGI community and has been found to outperform the other methods depending on the formulation of the problem [4]. The regularization technique imposes a prior on the inverse problem solution and weights the candidate solutions with the data-fidelity term in the cost function with a regularization parameter λ. Chamorro-Servent, *et al.*, proposes a new method called Automated Discrete Picard Condition(ADPC) in their study [5] to automatically find a suitable regularization parameter λ. This project report investigates the idea reported in *Improving the spatial solution of electrocardiographic imaging: A new regularization parameter choice technique for the Tikhonov method* [5].

The organization of the report is as follows:

- The problem and the proposed solutions to it are briefly introduced in this section.
- The background of ECGI and theory of the regarding inverse problem are discussed in Section Theory.
- The methods, datasets and the details regarding the implementation of proposed methods for both the original study and the reimplemented version with another experimental setup are shared in the Implementation section.
- Section Results and Discussion is left for the presentation of the results from conducted experiments along with the original results presented in the study and the discussion comparing the performances of the related method.

II. Theory

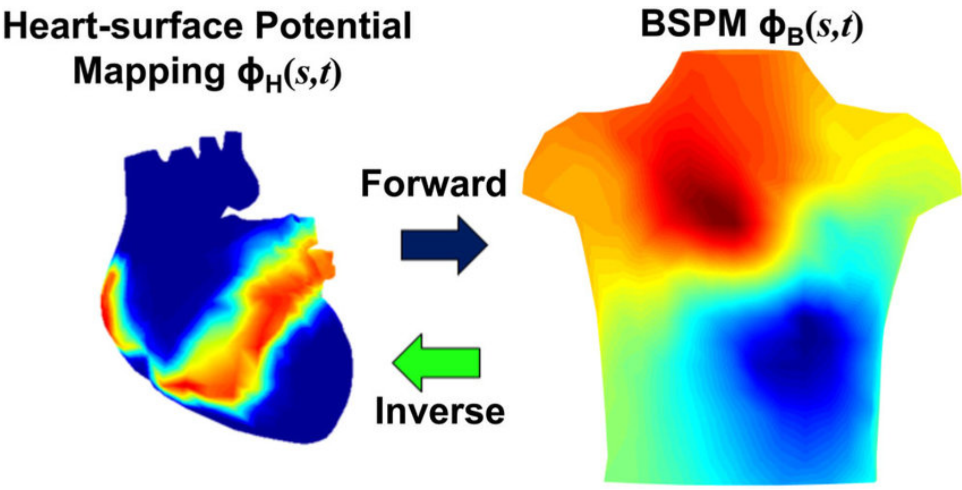

Figure 1: ECGI Forward and Inverse Problem

A. *ECGI Forward Problem*

ECGI Forward problem is constructing a model for calculating the body surface potential mapping(BSPM) from the given heart potentials, *i.e.*, the epicardial voltage distribution, shown by the right-side arrow in Figure 1. One can come up with different forward models for the ECGI problem. The authors of the original study utilized Method of Fundamental Solutions(MFS) method to derive the forward model, whereas Boundary Element Method(BEM) is utilized for the re-implementation.

Method of Fundemental Solutions

MFS is meshless approach adapted to ECGI. In this method, the measurements are expressed as a linear combination of fundamental solutions to the LapLace equation. It is formulated as

$$\Phi(x) = a_0 + \sum_{j=1}^{N_s} f(x - y_j)a_j \tag{1}$$

where $x \in \Omega$ where Ω is the measurement domain (torso) and y_j's are the N_s locations of the sources ($y_j \notin \Omega$) (heart). In this formulation f stands for the fundemental solution to LapLace equation in Eqn. 2:

$$f(r) = \frac{1}{4\pi}\frac{1}{|r|} \tag{2}$$

After the discretization of the domain on torso measurement locations, the following system matrix M can be obtained:

$$M = \begin{bmatrix} 1 & f(r_{11}) & \dots & f(r_1 N_S) \\ \vdots & \vdots & \ddots & \vdots \\ 1 & f(r_{N_T 1}) & \dots & f(r_{N_T} N_S) \\ 0 & \partial_{n_1} f(r_{11}) & \dots & \partial_{n_1} f(r_1 N_S) \\ \vdots & \vdots & \ddots & \vdots \\ 0 & \partial_{n_{N_T}} f(r_{N_T 1}) & \dots & \partial_{n_{N_T}} f(r_{N_T} N_S) \end{bmatrix}$$

B. ECGI Inverse Problem

C. Tikhonov Regularization

D. Parameter Choice Techniques

III. Implementation

IV. Results

V. Results and Discussion

References

[1] A. Intini, R. N. Goldstein, P. Jia, "Electrocardiographic imaging (ecgi), a novel diagnostic modality used for mapping of focal left ventricular tachycardia in a young athlete", *Heart Rhythm*, Vol. 2, No. 11, p. 1250–1252, 2005.

[2] C. Figuera, V. Suárez-Gutiérrez, I. Hernández-Romero, "Regularization techniques for ecg imaging during atrial fibrillation: A computational study", *Frontiers in physiology*, Vol. 7, p. 466, 2016.

[3] S. Schuler, D. Potyagaylo, and O. Dössel, "Ecg imaging of simulated atrial fibrillation: Imposing epi-endocardial similarity facilitates the reconstruction of transmembrane voltages", in *2017 Computing in Cardiology (CinC)*, IEEE, 2017, p. 1–4.

[4] M. Milani, V. Jazbinek, R. S. MacLeod, D. H. Brooks, "Assessment of regularization techniques for electrocardiographic imaging", *Journal of electrocardiology*, Vol. 47, No. 1, p. 20–28, 2014.

[5] J. Chamorro-Servent, R. Dubois, M. Potse, and Y. Coudière, "Improving the spatial solution of electrocardiographic imaging: A new regularization parameter choice technique for the tikhonov method", in *International Conference on Functional Imaging and Modeling of the Heart*, Springer, 2017, p. 289–300.