A survey on Inverse ECG (electrocardiogram) based approaches

Gaddam.Chandra Mohan1, DrSwapna Devi2
[1, 2] *Electonics&communication Engineering department, NITTTR, Chandigarh, India*

ABSRACT: *Analysis of Electrocardiogram signal involves variety of orientations .This paper investigates some of the important areas. Conventional methods are not in a position to deal with the heart related problems. Hence signal reconstruction oriented strategies like inverse problem oriented approaches are gaining momentum in nowadays. Early detection of arrhythmia is necessary to rectify the heart problem.Bruoga syndrome, atrial flutter, ventricular fibrillation, myocardial ischemia are some of the arrhythmias to be detected at an early stage.*
Optimized techniques can be useful to minimize the difference between the predicted potentials and recorded potentials of body surface.
Keywords: *Electrocardiogram, arrhythmia, inverse problem, body surface potentials.*

I. INTRODUCTION

ECG is the electrical activity of the heart measured through the heart potentials generated within the heart functioning like a electrical generator. Basically ECG signal is non stationary. The Reflection may occur at random in the time scale. The disease symptoms which are related to the heart may not show all the time but at certain intervals during the day. Small localized heart muscle damage may not be visible in the routine clinical ECG.All these limitations of ECG are to be rectified .Hence, comprehensive information may be obtained by using some methods like imaging, inverse problem, regularization for obtaining the desired solutions.

Early detection of arrhythmia will save a human life. Arrhythmia detection may not be possible alone using commercially available ECG equipment. Some computing techniques like optimization, imaging is useful for getting the desired properties of the signal. Inverse problem in electrocardiogram is to reconstruct epicardial potentials from body surface potential maps. In this method generally the source parameter that generates the measurements are reconstructed. The most common feature of many inverse problems is their ill posedness. This means that the solution of this problem is not unique. Even small disturbances in the measurements lead to unbounded errors in the solution. In order to stabilize the solution of the problem additional assumptions have to be introduced into the formulation. In other words, a procedure called regularization where priority constants are used to make less sensitive to perturbations.

Arrhythmia detection: Burga syndrome is one type of arrhythmia which causes sudden death in young adults .Analysis of the electrical activity by recording epicardial or endocardial electro grams (EGM) is a valuable for understanding pathological conditions. However recording of EGMs is an inverse procedure only performed in patients already diagnosed with this syndrome. Computing EGMs by non-invasive recordings by solving inverse problem has been presented in [1]. This inverse computed EMGs were compared to those of control subjects in terms of activation times and duration.

A leading cause of death in the western world, myocardial ischemia occurs when cardiac myocates are damaged for lack of oxygen.ECG diagnostics of a myocardial ischemia relies on detecting the elevation of the normally isoelectric ST segment.

This is caused by the injury contents resulting from the transmembrane voltage diifference between healthy and ischemic tissues. A constrained optimization framework for solving has been propose in[2].Here the attempt has been made to localize ischemia by inversely computing the transmembrane potentials(TMP)s through the myocardium from the voltage measured at the body surface. This method does not compute the lead field matrix hence it has lower computational cost. Secondly as it allows flexible discretization resolution for the TMPs and other state variables.

Computational models of the heart have evolved to become an important tool for understanding several types of arrhythmias like AF (atrial flutter) or ventricular fibrillations. Various genetic diseases like long QT or short syndrome can be simulated successfully. A framework has been suggested in order to adopt a generalized model of the human atria to the heart of an individual in[3].In this framework a method is applied that allows for the detection of the local direction of a wavefront and the conduction velocity (CV) of a circular multi electrode catheter. For the validation of the segmentation algorithm the standard methods of medical imaging have been used.

Spatial patterns of body surface potential maps(BSPM) recorded during ballon inflatory percutoneous translurinalcoronary angioplasty(PTCA) in patients with single vessel coronary artery disease have been examined in[4].It is also investigated how well these patterns can be predicted in just 8 independent leads of the 12 lead ECG.Further ,by using inverse solution it also estimated heart surface potential maps from both 120 lead BSMPs and from those derived from 12 lead ECG s by comparing solution. A boundary element torso model was used to estimate the heart surface potential s from body surface potential maps (BSMP) obtained from 12 lead ECG via transformation developed from a designer set of 120 lead ECGs by a least square solution to the linear regression problems. This study shows that for patients with acute myocardial ischemia both the body surface and potential surface maps estimated from the 12 lead ECGs correlate well with those constructed from the 12 lead ECGs.This approach is very much useful in ischemia detection.
Real time oriented approach: Development of tele cardiology systems is a very low cost and realistic system.
The first step in this regard is to build up an automatic ECG analysis system. An efficient algorithm which performs pattern recognition to extract the time plane features of an ECG wave presented in [5].This approach is also further evaluates

clinically required parameters. Any cardiac disease diagnosis can be made on the knowledge basis of abnormal parameters. The basic software package here detects patterns, delianates time plane features and calculates clinical measurements of ECG wave. Hence it can be extended further a cardiac disease inference engine by just configuring different conditions to diagnose generation (3G) cellular network rollout.

Hence uploading the digital image of ECG strip will almost take notime.Nowadays the processing capability of the mobile phones increases in the future the entire process could be assimilated in the mobile phone. Thus the entire concept may be fruitful for remote telemedicine as an application.

Optimization: Finding activation times on the heart non invasively from body surface potential s in inverse ECG problem is known as nonlinear least square optimization problem. A mathematical framework for the original NLLS optimization problem and reformulate it as an equivalent non constrained optimization. Based on this framework isolate the non convexity of the problem to a single constraint on the domain of the optimization variables has been propose in [6].This method has been formulated is a convex relaxation to the original problem by removing the isolated nonconvex content. This method is based in the context of potentially based formulation for the inverse problem that is with the unknowns being free transmembrane potential value at each point on the heart surface at each time instant.

The objective function of an optimization problem used to rank the suitability of a candidate solution. But sometimes there is a mismatch between the objectives of activation based inverse ECG and the objectives of activation based inverse ECG and the objective function of the corresponding optimization problem. This approach suggests that the optimization criteria for the problem need to be carefully reviewed and modified, if necessary to achieve the intended goals. A procedure for activation based inverse ECG as applied to data measured from a patient with wolff-parkinson white(WPW) syndrome has been presented in[7].In this experiments ,number of optimization problems like fastest route algorithm(FRA) initialized non linear square(NLLS) ,a convex relaxation of the NLLS problem and a sequence of NLLS problem. A method based on a convex optimization frame work to explore the solution space used and whether the optimization criteria target and their intended objective FRA also has been analysed.

Inverse problem approach: Basically, Inverse problem constitutes a particularly demanding task as for as computational resources are concerned. The use of proper orthogonal decomposition (POD) for the very fast solution of the forward problem in the form of a selected Eigen function has been proposed in [8].This approach yields a very efficient solution of the inverse problem as it involves multiple forward problem solution at each iteration. The proposed method in the context of current effort adopts a combined utilization of POD along with finite element method (FEM) on a realistic human torso model for rapid solutions of the inverse ECG problem.

This algorithm was tested on multi channel available online. In this procedure the body surface potentials were measured from 128 electrodes positioned equidistantly over the body surface. Inverse problem of ECG can be described as the estimation of cardiac electric sources like the epicardial potential distributions using the body surface potential measurements (BSP).The cardiac electrical source distribution provides useful information about the functioning of the heart. However the inverse ECG problem is illposed.Even a small amount of noise causes unbounded errors. To overcome this drawback various regularization methods were applied in the published literature.Tikhanov regularization is one of the most widely used approach. This method tries to reach a trade off between a good fit to the measurements and a priori information about the solution. This trade off is achieved using a regularization parameter which is usually found using the L curve approach. A method by using Genetic algorithm to estimate the regularization parameters proposed in[9].Here the inverse ECG problem has been by using multiple constraints approach. The genetic algorithm (GA) has been used to estimate the regularization parameters, hence the number of unknowns decreases significantly.

There is a notable gap in the literature regarding the impact of resolution on the practical forward and inverse problems for the finite element method. A study has been focussed on to develop refinement strategies involving hybrid shaped finite elements so as to minimize approximation errors for the ECG inverse problem in[10].This approach examines both the ill posedness of the mathematical inverse problem and the ill conditioning of the problem. The aim of this study was to investigate optimal discretization strategies for the optimizing for the existing regularization schemes. It is observed that refinement strategies developed only for optimizing the forward problem may be inappropriate for the corresponding inverse problem. Resolution strategies include determining the resolution on the heart surface, volume conductor and decomposing the resolution in the tangential and normal direction near the heart surface. The results obtained from the annulus model and the realistic torso model indicated that discretization refinement itself is one form of regularization and can be combined with other classical regularization techniques to further improve the inverse solution.

Regularization is the technique to stabilize the solution in inverse problem. In the published literature tikhanov regularization, truncated singular value decomposition (TSVD) etc.are some of the popular methods. These regularization methods need a certain parameters to solve the inverse problem. L curve method can be used to obtain these parameters. Distribution of electric potentials over the surface of the heart, also called epicardial distributions is a valuable tool to understand the defects in the heart functioning.Diret measurements of these potentials is a highly invasive procedure. Alternatively to reconstruct the epicardial potentials noninvasively from the body surface potential maps is known as inverse problem of ECG.The study to solve the inverse ECG by using by using several regularization methods and comparing their performance has been presented in[11].The performance of regularization methods for solving the inverse ECG was also evaluated on a realistic torso model simulation protocol. It is also investigated the use of genetic algorithm for regularizing the ill posed inverse ECG problem .The results show that GA is an efficient optimization technique for improving the solution of the illposed inverse problem.

An indirect iterative method for solving the inverse problem in the terms of multiple moving dipoles has been proposed in [12].This method based on muti polar representations of the heart electrical activity. Surface potentials generated by multiple dipoles are iteratively combined to maximize similarity between computed and recorded potentials. The performance of algorithm tested by localizing electrical dipoles from simulated surface potentials in an eccentric spheres model of human torso. Limitations of iterative search strategies are more evident when two simulation dipoles are searched. The accuracy in this indirect method will be dependent on the amount of surface potentials stored for comparison which limits the spatial resolution used for the construction of the database.

One main form of the inverse problem in ECG constitutes the reconstruction of epicardial distributions (EP) from the measured body surface potentials(BSP).As inverse problem is ill posed regularization process has to be applied to get the physiolocally meaningful EPs.In the regularization process the regularization parameter is the key step. Two new regularization parameter selection methods cross validation procedure(CVG) and L curve in the context of total least squares(TLS) are presented in[13].These new methods consider both sides of noise in the linear system equation ax=b using the realistic heart lung torso model. The CVG method seems to be more suitable for parameter selection to the clinical inverse ECG problem because of existing measurement and geometric errors which are inherently prevailing.

Conclusion: Inverse problems are basically seeking the Source from obtained potentials. Body surface potentialsbe calculated from the torso models by using forward problem approach. Source potential estimation by inverse problem is useful for the source from the available body surface potentials. Regularization approach will smoothify the ill posed problem into acceptable solution. Arrhythmia detection methods ill be useful to rectify the problems at an early stage.

Future orientation: Extending the study of realistic ECG problem i n three dimensions is the challenging issue. Properly defining the heart spatial frequency spectrum on the 3D surface and to assess the epicardial information on the heart surface are the issues for further investigation.Computional resources also major constraints in practical simulations.

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