THE EFFICACY OF THE HYBRID INTERPOLATION METHOD IN RECONSTRUCTING THE MISSING DATA IN BODY SURFACE POTENTIAL MAPS

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INTRODUCTION

Recording the electrical activity of the heart using 10 body surface electrodes (the standard 12-lead ECG) reveals diagnostic information about cardiac arrythmias. Several studies has shown that more information can be obtained when increasing the number of recording electrodes as in body surface potential mapping (BSPM) [1]. Studies have reported how BSPMs improve the detection of MI [2] and identification the site of origin of cardiac arrythmia [3]. In addition, BSPMs are an essential part of ECG imaging (ECGi), a novel non-invasive modality that is used in the clinical practice for accurate identification of the site of origin of atrial and ventricular arrhythmias [4]. Given the high number of electrodes in the Recording of BSPMs, it becomes inevitable to lose some of this information due to applying defibrillation pads or Carto patches or because some of these electrodes become detached or poorly connected. This results in a negative impact on the diagnostic value of BSPM or the epicardial potentials computed from them [5]. Reconstructing this missed information using different interpolation methods such as Laplacian interpolation, Inverse-forward interpolation, spline interpolation, and local barycentric have been studied in the literature to resolve this issue [5]. In this paper, we compare the effectiveness of different interpolation methods including the hybrid interpolation method in reconstructing the missing data in BSPM.

METHODS

Dataset

The original recording of this dataset was at Dalhousie University, Halifax, Nova Scotia [6]. The dataset used consisted of 117 lead BSPMs recorded from 744 subjects. The patient population consists of 229 normal subjects, 278 subjects with old myocardial infarction (MI), and 237 subjects with left ventricular hypertrophy (LVH). BSPMs were recorded for all subjects. Digitized ECG signals were recorded simultaneously from 117 recording sites on the anterior and posterior portion of the subject's torso with reference to Wilson's central terminal and at a sampling rate of 500 samples/second/channel.

Interpolation methods

The effectiveness of different interpolation methods including Laplacian interpolation [7], PCA interpolation [8, 9], and the hybrid interpolation method [10] in reconstructing the missing data in five configurations of the missed leads: ML1: defibrillation pad 1, ML2: defibrillation pad 2, ML3: Carto electrodes, ML4: Torso sides, ML5: Combination of ML2, ML3, and ML4 were investigated (Figure 1). Two independent and widely used metrics including root mean square error (RMSE)

Figure 1. Configuration of the missed leads on the body surface. ML1 to ML5 simulate the common missed leads in the clinical practice

and correlation coefficient (CC) between the recorded and computed ECG were used to compare between these interpolation methods.

RESULTS

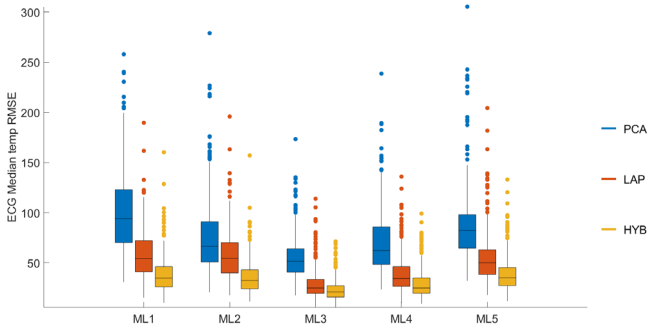

Figure 2. ECG median RMSE between the recorded and interpolated ECGs for each missed lead configuration when PCA, Laplacian, and hybrid interpolation methods were used.

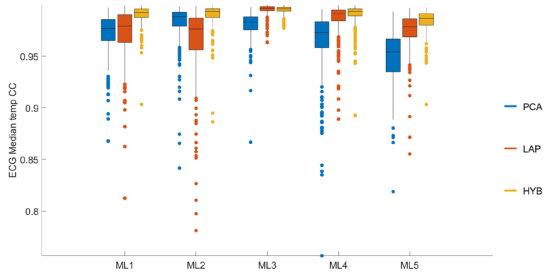

Figure 3. ECG median CC between the recorded and interpolated ECGs for each missed lead configuration

when PCA, Laplacian, and hybrid interpolation methods were used.

Figure 2 presents the comparison between the three interpolation methods in terms of median RMSE. There was a significant decrease in the value of median RMSE when the hybrid method was used as compared to when the other two methods were used. The greatest reduction was noticed in ML1 where the numbers wend down from 93.84 [70.24 - 122.92] and 54.33 [40.9 - 72.08] for the PCA and Laplacian interpolation methods to 34.78 [25.99 – 46.12] for the hybrid interpolation method. The same trend was noticed for the other missed lead configurations with the lowest reduction was in ML3.

Figure 3 shows the results in terms of median CC. When the hybrid interpolation was used, the values were 0.992 [0.988 – 0.996], 0.993 [0.987 – 0.996], 0.996 [0.994 – 0.997], 0.993 [0.989 – 0.996], and 0.986 [0.98 – 0.991] for ML1 to ML5, respectively. In contrast, these values were 0.979 [0.963 – 0.99], 0.976 [0.956 – 0.987], 0.996 [0.994 – 0.998], 0.991 [0.984 – 0.995], and 0.978 [0.969 – 0.986] when the Laplacian interpolation was used, and 0.977 [0.965 – 0.985], 0.989 [0.979 – 0.993], 0.983 [0.976 – 0.988], 0.973 [0.958 – 0.983], and 0.954 [0.935 – 0.967] when the PCA interpolation was used. The hybrid method performed the best except for ML3 where the Laplacian interpolation performed better than the other methods.

DISCUSSION

Laplacian interpolation has been used previously for this purpose [5].It considers some of the physical properties that govern the distribution of the potential field on the body surface by recognizing that the second spatial derivative of the potential field over the body surface is zero [5]. PCA based interpolation performs the interpolation by comparing the BSPM that contains some missing values with previously recorded BSPMs and estimate the missing values based on the similarity between them. This method did not perform as well as Laplacian interpolation especially when the number of missing electrodes is high, which happens frequently in the clinical setting. A novel hybrid method was developed in this current study to obtain better interpolation results. In this method, the interpolation was performed in the same way as in the PCA method except that the comparison between the BSP maps was performed after estimating the missing values using Laplacian interpolation. This employment of the two methods of interpolation resulted in a more accurate estimation of the missing potential values in all simulated regions of missing data.

CONCLUSION

The novel hybrid interpolation method performed better that PCA interpolation and Laplacian interpolation methods for reconstructing the lost data due to missed leads in BSPM recordings.

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