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Heart state estimation from electrocardiograms

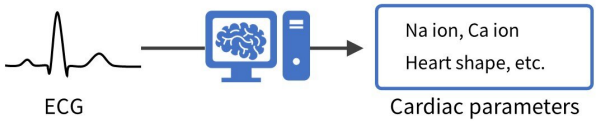
How active are your heart cells?

Abstract

This study addresses the estimation of parameters affecting the shape of ECG waveforms. The parameters include electrical conduction velocities and potential activation patterns that control the behavior of cardiomyocytes. Although the broad correspondence between diseases and ECG waveforms has been well studied, it has been difficult to estimate cardiac status at the cellular level from an observed ECG. This study enables its estimation using an artificial neural network trained with a set of ECGs generated by an existing ECG simulator. It is expected that the estimated parameters can be used for detailed and individualized cardiac status analysis. After evaluating this method in a clinical environment, we want to introduce this technique to our bio-digital twin that can predict personalized health status and simulate medical care.

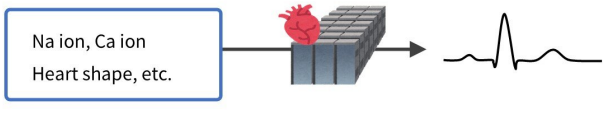
Background

- Electrocardiogram (ECG) analysis
  - Existing methods estimate specific anomalies and diseases from ECGs.
  - Our method estimates the cellular-level parameters affecting the shape of ECGs.
    - › Estimated parameters can be used for detailed and personalized heart state analysis.

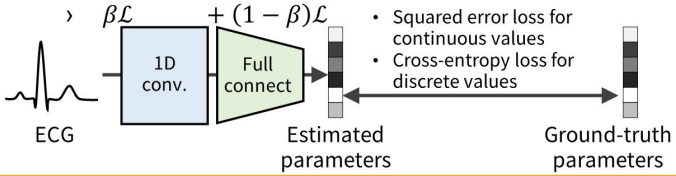


Method

- AI (deep learning)-based cardiac parameter estimation
- Training data collection
  - ECG synthesizers[1, 2] were used.
  - Both continuous or discrete cardiac parameters were used.

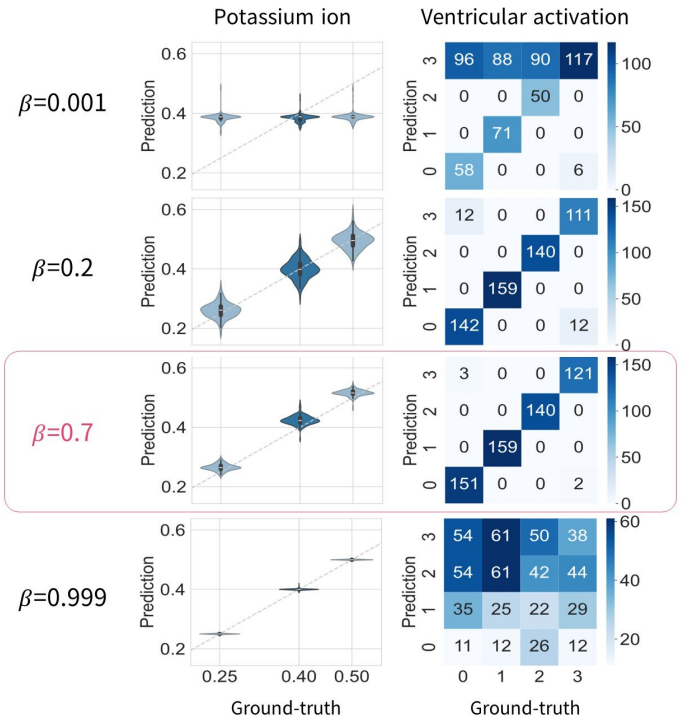


- Composition and training of the estimation method
  - β: weight to adjust the balance of the loss functions
    - › $\beta\mathcal{L}_{\text{continuous}} + (1-\beta)\mathcal{L}_{\text{discrete}}$



Experiment

- Performance is stabilized by weighting that emphasizes continuous cardiac parameters.



Performance of the cardiac parameter estimation for the different values of the weight β

Left figures: scatter plots of the continuous cardiac parameters
Right figures: confusion matrices of the discrete cardiac parameters

Future work

- Verification of the proposed method in a clinical environment

References

[1] S. Sugiura, T. Washio, A. Hatano, J. Okada, H. Watanabe, T. Hisada, "Multi-scale simulations of cardiac electrophysiology and mechanics using the university of Tokyo heart simulator," *Progress in Biophysics and Molecular Biology*, Vol. 110, pp. 380–389, 2012.
[2] R. Nishikimi, M. Nakano, K. Kashino, S. Tsukada, "Variational autoencoder–based neural electrocardiogram synthesis trained by FEM-based heart simulator," *Cardiovascular Digital Health Journal*, Vol. 5, Issue 1, pp. 19-28, 2024.

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