Smart Mathematics for the Inverse Problem in Electrocardiography

8 Impact

SCIENTIFIC IMPACT

Regularization parameter selection Our investigation provides a systematic analysis of which parameter settings are good when solving ventricular ECGI using Tikhonov regularization. We provides an overview of the strong and weak points of the available selection methods in an absolute sense. In lieu of using methods that may fail in certain cases, we also promote the use of a fixed parameter value, especially when computational efficiency or consistency across time is required.

Streamlined ECGI procedure We propose the deep learning framework to reformulate ECGI from an inverse problem to an image-to-image translation task, eliminating the need for radiology. Combining ECGI with artificial intelligence (AI), this framework comprises three integral components: (1) 2D torso representation and body surface potential maps (BSPMs), (2) 2D ventricle and atrium representation and heart surface potential maps (HSPMs), (3) optimized sequential cGAN (ScGAN) deep learning model. The proposed radiology-free framework can quickly and easily produce HSPMs that closely resemble ECGI reconstruction results. It only requires information about body surface recordings and electrode positions to generate the BSPMs. And electrode positions can be obtained using simple vision techniques without the need for CT or MRI scans.

User-friendly and effective visualization tool The 2D representations of the torso, ventricles, and atria serve as a user-friendly and efficient visualization tool. Refined for simplicity, clarity, and accuracy, these representations capture the essential details of the original 3D anatomy. They simplify the observation and comparison of electrophysiological and anatomical information across subjects, which facilitates cardiac-related scientific research.

A practical framework We convert 3D geometries into full rectangular 2D representations and use a deep learning model to predict HSPMs from BSPM. While the design of this framework is originally conceived to solve the inverse problem in ECGI, it can also be applied to other problems that require exploring intricate relationships between two different domains. This framework serves as a valuable tool for various complex mapping tasks.

CLINICAL IMPACT

Enhancement of the catheter ablation procedure The 2D representations can simplify the catheter ablation process by allowing electrophysiologists to quickly identify abnormal patterns without frequent interactions with clinical technicians. These mappings provide clear visualization of features that are crucial to the ablation procedure but are only visible in 2D views, improving the success rates of ablation procedures. They also enable easy and quick comparisons across different subjects, which is very convenient for group analysis after the procedure, contributing to better analysis of treatment outcomes and development of more effective treatment plans.

Simplified data collection In the proposed deep learning framework, only simple vision techniques, such as a 3D camera system is need to obtain torso related information. This eliminates the need for CT or MRI scans, making the process radiation-free, reducing scanning time, and eliminating the need for specialized equipments. By avoiding CT/MRI, trained personnel are not needed, which reduces labor costs. Additionally, this reduction in procedural complexity enhances patient comfort and makes the technique more suitable for routine clinical applications.

Easy clinical deployment As a lightweight tool for cardiac activity reconstruction, this radiology-free approach is easy to be deployed in clinical settings. For a patient requiring frequent visits to the clinic (torso information is obtained on the first visit), a well-trained, subject-specific deep learning model can facilitate ongoing monitoring and testing, enabling personalized treatment plans.