CardioNet: Synthesis of a Diagnostic-Caliber 12-Lead Electrocardiogram Using Generative Neural Networks and Novel Feature Extraction Techniques

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Cardiovascular disease (CVD) is the leading cause of death in the United States. However, early detection can prevent up to 80% of associated fatalities. 12-lead Electrocardiograms (ECGs) are the gold standard for CVD diagnosis but require special equipment to be recorded. Smart wearable devices are ideal for at-home monitoring but only record three leads, limiting detectable diseases. This abstract introduces CardioNet, a method to synthesize a diagnostic-caliber 12-lead ECG from a subset of leads. CardioNet uses Leads I, III, and V6 to generate the remaining nine leads. Leads II, aVR, aVL, and aVF are calculated using proven methods (Einthoven and Goldberger Formulas), while Leads V1-V5 are synthesized using a novel machine-learning pipeline, the project's primary focus. CardioNet utilizes a novel multi-scale transformer architecture that processes single-beat, coarse-grained, and fine-grained representations of the input leads using 3 distinct pipelines each implementing custom-designed transformer blocks (e.g. CNN+Transformer, custom positional encodings). This architecture is designed to analyze both local (Single Beat) and temporal (Multi Beat) dependencies, ensuring a diagnostic-caliber ECG output. The model is trained using 100,000 ECGs split between 10 disease types from the Mimic-IV database. CardioNet achieved a low error with an average NRMSE of 0.00013 and an AAE of 0.016 mV when tested with 30,000 ECGs. The synthesized ECGs were also proven to be diagnostic caliber when evaluated by a licensed cardiologist for accuracy of morphology in both normal and abnormal ECGs. CardioNet is the only method for 12-lead ECG synthesis using wearable devices, and its novel generative AI methodology makes early detection and at-home monitoring of CVD widely available.