Feasibility of ECG Reconstruction from Minimal Lead Sets Using Convolutional Neural Networks

Maksymilian Matyschik, Henry Mauranen, Pietro Bonizzi, Joël Karel

Department Of Data Science and Knowledge Engineering, Maastricht University, The Netherlands

Aim: Reconstruction of 12-lead ECGs from a minimal number of leads can be relevant for wearables and continuous monitoring. Artificial neural networks have shown promising preliminary results. We investigate the use of convolutional neural networks (CNNs) for ECG reconstructions, and variational autoencoders (VAEs) for interpreting relevant signal components for model fitting.

Methods: The T-Wave Alternans Challenge database (TWA) was used for CNN reconstruction (voltage levels were scaled to [-1,1]) and PTB Diagnostic database for VAE component analysis. Both datasets contain 12-lead ECG recordings from healthy subjects and patients. One model per CNN architecture was trained on each lead separately, whereas VAE based architectures were trained on 12 leads jointly and over multiple patients with the same heart condition to learn the complete ECG process. Reconstruction performance was assessed on the first database, while neural network analysis via gradient-weighted class activation was performed on the second database.

Results: For TWA, the best architecture achieved an average mean squared error (MSE) of 0.02 within scaling bounds (highest 0.67) and Pearson's r of 0.77 (lowest -0.07), compared to the least squares optimization baseline which yielded 0.08 (highest 1.0) and 0.0 (lowest -0.54), respectively. The results from VAEs display the most influential regions to be QRS-complex and T-wave for healthy patients, and emphasise leads close to the heart. This analysis was repeated for 7 different heart conditions, where we found the networks' focus to be around similar regions as for healthy subjects.

Conclusions: We observed that V2, V3 and V4 leads are the most significant ones for reconstruction of ECG recordings, while leads such as aVL contain only a small portion of useful data. These results differ between heart conditions. Our CNN architecture can be used to reliably learn and reconstruct 12-lead ECG recordings from one selected lead, with personalized models.