Performer: A Novel PPG to ECG Reconstruction Transformer for a Digital Biomarker of Cardiovascular Disease Detection

Lan, Ella (School: The Harker School)

Cardiovascular diseases (CVDs) have become the #1 cause of death; three-quarters of these deaths occur in lower-income communities. Electrocardiography (ECG), an electrical measurement capturing cardiac activities, is a gold standard to diagnose CVDs. However, ECG is infeasible for continuous cardiac monitoring due to its requirement for user participation. Meanwhile, photoplethysmography (PPG) is easy to collect, but the limited accuracy constrains its clinical usage. In this research, a novel Transformer-based architecture, Performer, is invented to reconstruct ECG from PPG and to create a novel digital biomarker, PPG along with its reconstructed ECG, as multiple modalities for CVD detection. This architecture, for the first time, performs Transformer's sequence to sequence translation on biomedical waveforms, while also utilizing the advantages of the easily accessible PPG and the well-studied base of ECG. Shifted Patch-based Attention (SPA) is created to maximize the signal features by fetching the various sequence lengths as hierarchical stages into the training while also capturing cross-patch connections through the shifted patch mechanism. This architecture generates a state-of-the-art performance of 0.29 RMSE for reconstructing ECG from PPG, achieving an average of 95.9% diagnosis for CVDs on the MIMIC III dataset and 75.9% for diabetes on the PPG-BP dataset. Performer, along with its novel digital biomarker, offers a low-cost and non-invasive solution for continuous cardiac monitoring, only requiring the easily extractable PPG data to reconstruct the not-as-accessible ECG data. The creation of healthcare wearable PEARL (prototype) also potentially opens a new door to scale up the point of care (POC) healthcare system.

Awards Won:

Third Award of $1,000