Prediction of cardiovascular parameters by impedance cardiography using machine learning.

Analysis of signals from impedance cardiography and the correlation to pumping capacity of the heart.

Graduate

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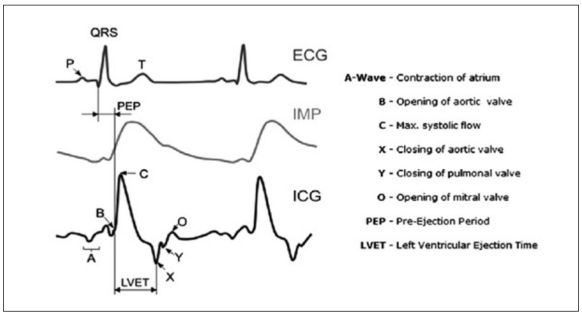
Introduction: Heart insufficiency or heart failure, affects around 150'000 people in Switzerland, reducing heart pumping power and severely limiting quality of life, with patients struggling with daily activities. Early detection, especially in younger patients, offers a better prognosis. Heart failure and related conditions cost the healthcare system about 8 bn CHF annually, creating an economic incentive for better early detection and treatment methods, e.g. using non-invasive monitoring systems. Current methods extract key points in electrocardiogram (ECG), electrical impedance (IMP) and impedance cardiography (ICG) signals to calculate time deltas correlated with cardiac function. This thesis aims to replace these conventional methods with machine learning (ML), enhancing prediction accuracy and robustness. Haemodynamic parameters like stroke volume (SV), pre-ejection period (PEP), left ventricular ejection time, and total peripheral resistance were measured from 20 subjects to serve as labels for recorded signals, providing data to train models.

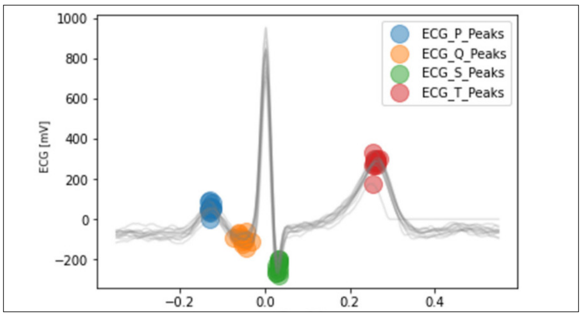
Approach: The ML algorithms used can be categorised into traditional models (Random Forest, XGBoost, etc.) and deep learning (DL) models (CNN, LSTM). For the traditional models, sophisticated methods were used to extract features such as the time differences between the characteristic points in the ECG, IMP, and ICG signals to predict the target variables. For the DL models, the ECG, IMP and ICG signals were filtered, reduced to individual heartbeats and used as 3-channel time series input for the neural networks. The models were trained with and without additional metadata such as age and BMI.

Conclusion: We find that the accuracy of the prediction of the traditional models (shown here for the systemic vascular resistance) based on hand-crafted features such as heart rate or ICG peak amplitude perform better (R^2=0.90) than models based on a CNN (R^2= 0.82). Additional metadata increase the accuracy. In future, more data shall be recorded using smart textile electrodes to further increase the robustness of the prediction.

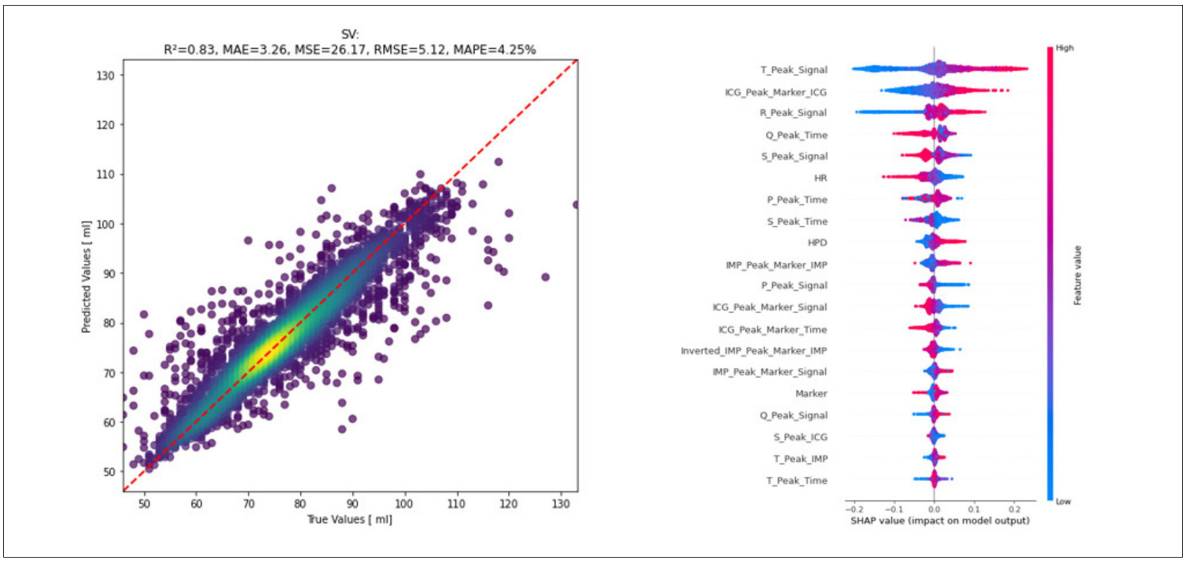
Key values for the ECG, IMP and ICG signal and connection to PEP and LVET value.
Own presentment



Extracted heartbeats with peak selection by wavelet transformation for the characteristic points of the ECG
Own presentment



Deep Learning-model for SV prediction with an R2 of 0.82 and with SHAP values for model explainability.
Own presentment



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Subject Area
Data Science