Improving Multiclass Classification of Cardiac Arrhythmias with Photoplethysmography using an Ensemble Approach of Binary Classifiers

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Agenda

01 Introduction

02 Related Work

03 System Design

04 Experimental Evaluation

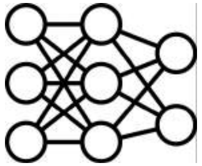
Motivation

cardiac arrhythmias are one of the leading causes of death worldwide

17.8 million deaths [1]

primary method for the detection of arrhythmias is the electrocardiogram

300 million ECG-strips [2]



classification of arrythmias with ML and DL based on ECGs

1 worldwide in 2017
2 worldwide per year

Motivation

ECGs are used in a medical context and
do not allow long-term monitoring

application of photoplethysmography (PPG)
in smart devices to detect arrhythmias

classification of multiple arrhythmias
based on PPGs are limited

Improving the classification of various heart rhythm abnormalities by an ensemble of binary classifiers

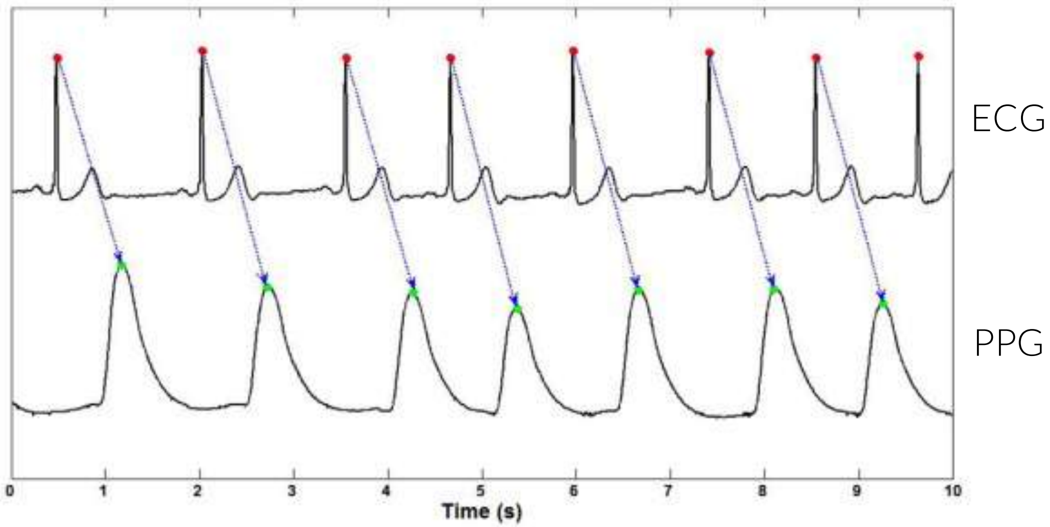
ECG and PPG

ECG

- measures the electrical activity of all heart muscle fibres
- low portability
- maximum time of monitoring ≈ 3 days
- accurate

PPG

- measures the volumetric changes of blood in the microvascular tissue bed
- build into smart divices
- constant monitoring
- can be inaccurate



V. Kalidas and L. S. Tamil, "Cardiac arrhythmia classification using multi- modal signal analysis," Physiological Measurement, vol. 37, pp. 1253–1272, jul 2016.

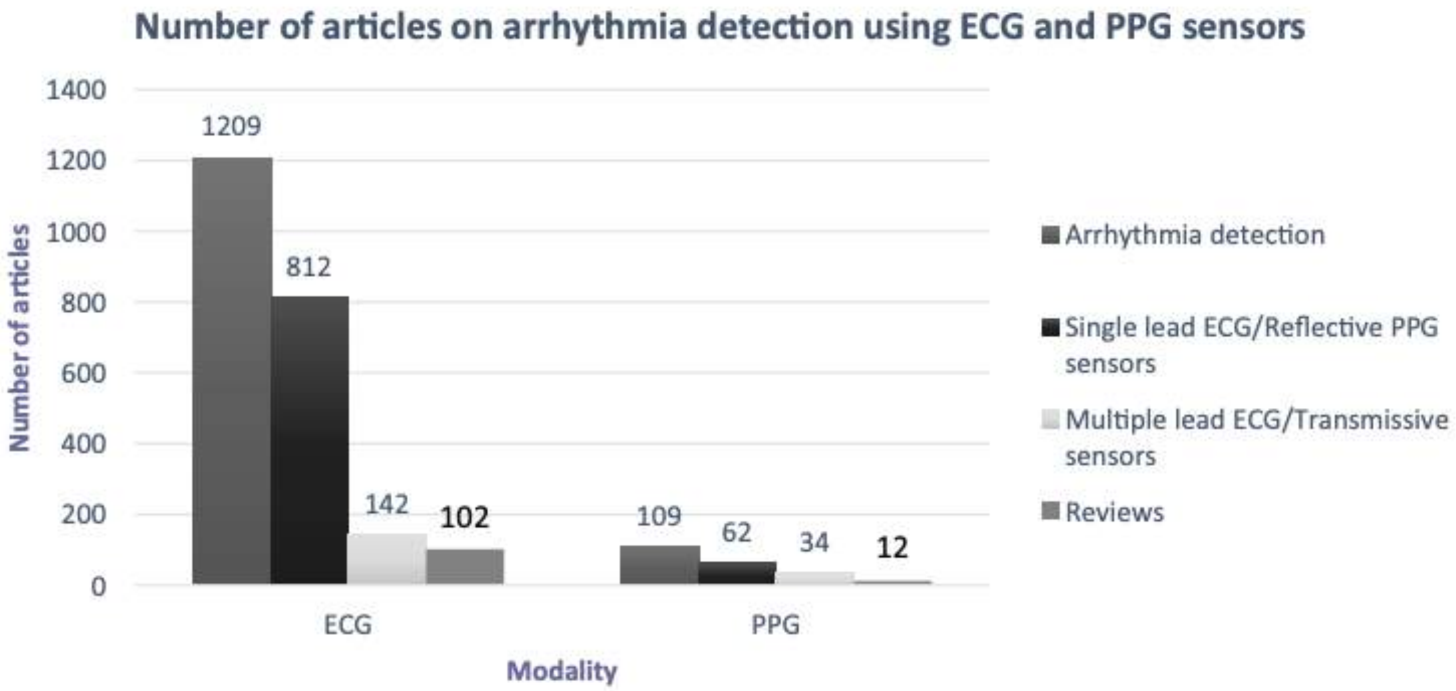
PPGs and ECGs are related to each other

- peak of ECG = contraction of ventricles
- transport of blood through the veins

  → blood valume increases

Related Work

- more research with ECG data
- approaches include statistical methods, machine learning, deep learning, etc.
- focus in publications with PPG data is primarly on the single-class classification



Neha, Sardana, H.K., Kanwade, R. et al. Arrhythmia detection and classification using ECG and PPG techniques: a review. Phys Eng Sci Med 44, 1027–1048 (2021). https://doi.org/10.1007/s13246-021-01072-5

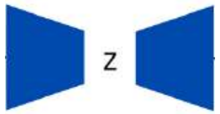
Multiclass Arrhythmia Detection from PPG Signals

- multiclass classification of five arrhythmias and sinus rhythm
- deep convolutional neural network (DCNN) based on the VGGNet-16 architecture
- own dataset with 228 patients and 118,217 10-second sequences
- inter-patient approach

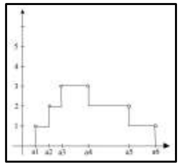
→ accuracy: 85% (imbalanced dataset)

Multiclass Arrhythmia Detection from ECG Signals

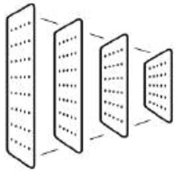
combination of topological data analysis, handcrafted features, Fast Fourier Transformation, and deep learning



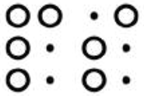
Autoencoder:
- compensation between normal and abnormal heart rhythm
- trained with sinus rhythm



Betti Curve:
- from ECG-sequences
- curve is processed in an CNN



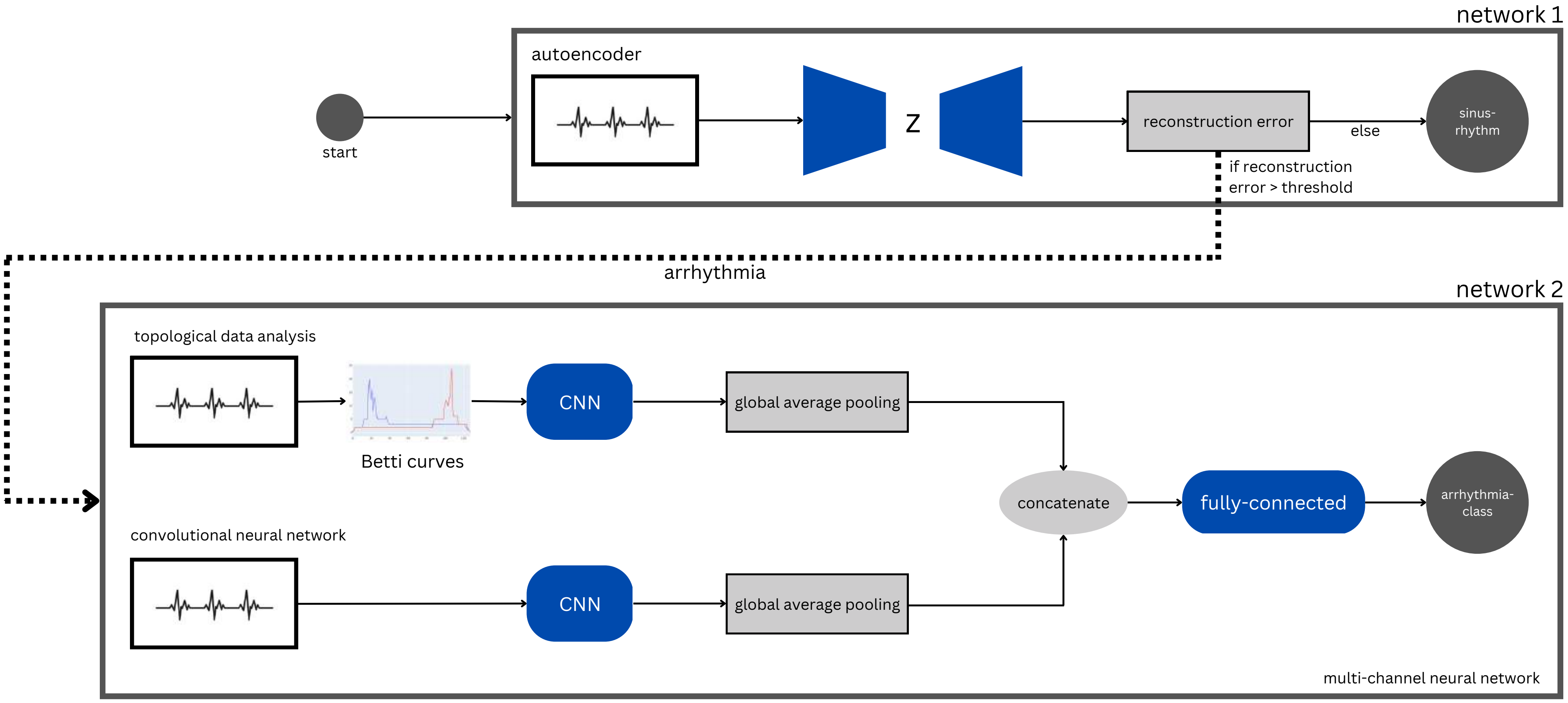
Convolutional Neural Network:
- signal as input



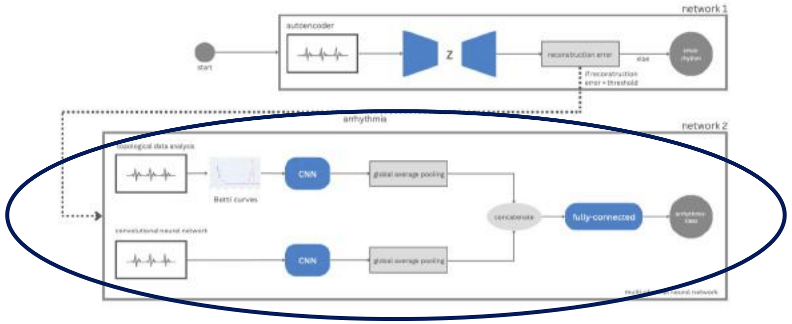
Others:
- Fast-Fourier-Transformation
- handcrafted features

➡ model architecture as a baseline for the classification of arrhythmias with PPG data

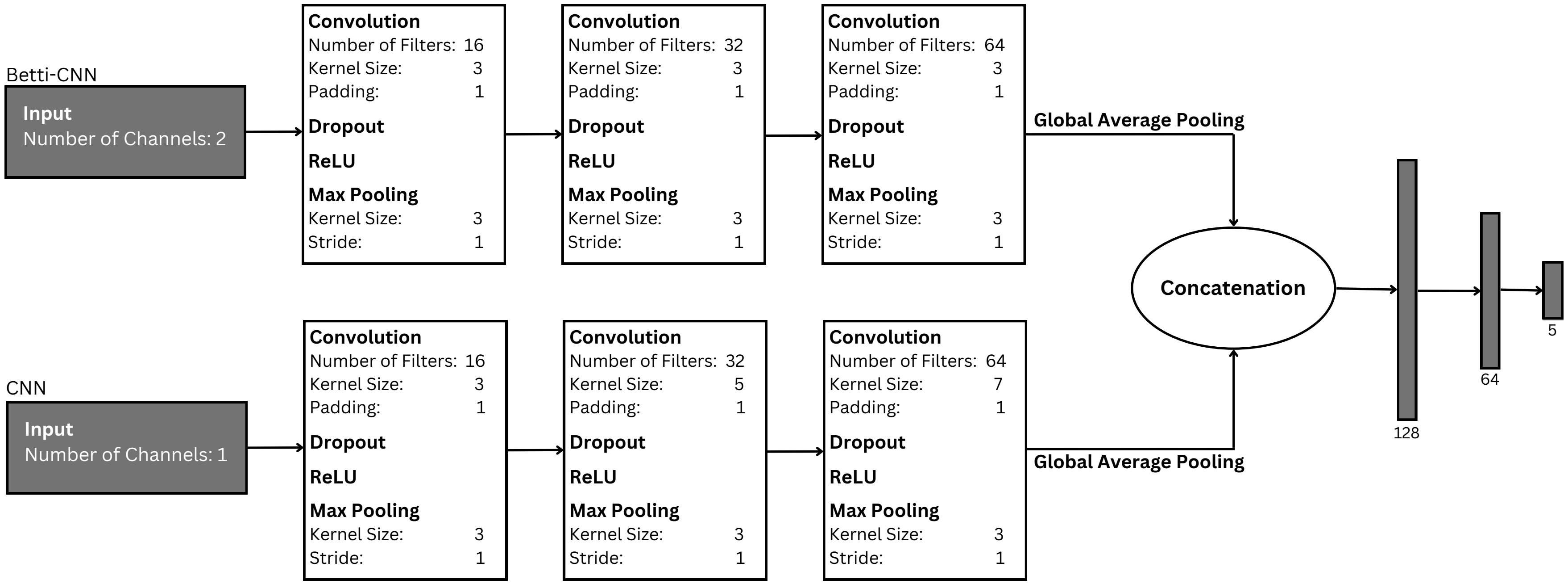
Model Architecture



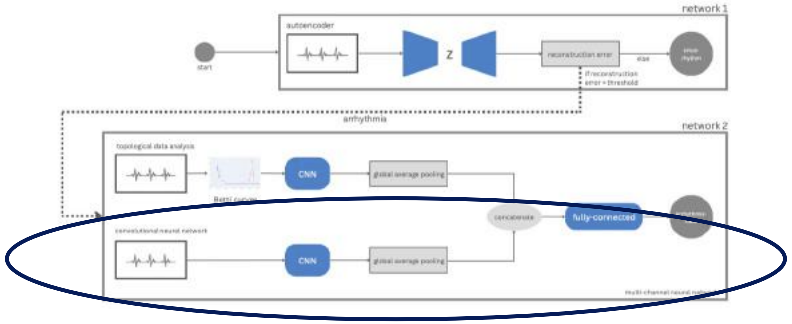
Multiclass Model Architecture Multiclass



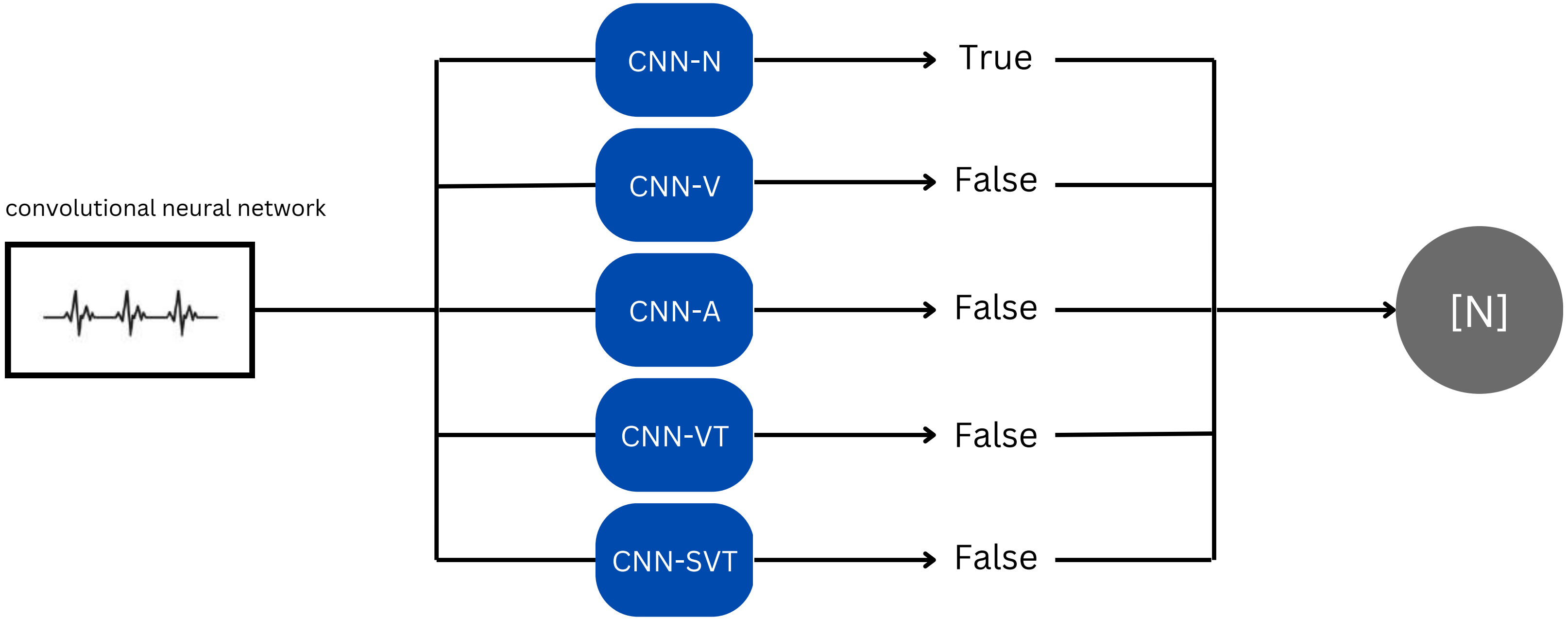
- application of small model architectures due to the small number of available samples
- model outputs one of five classes



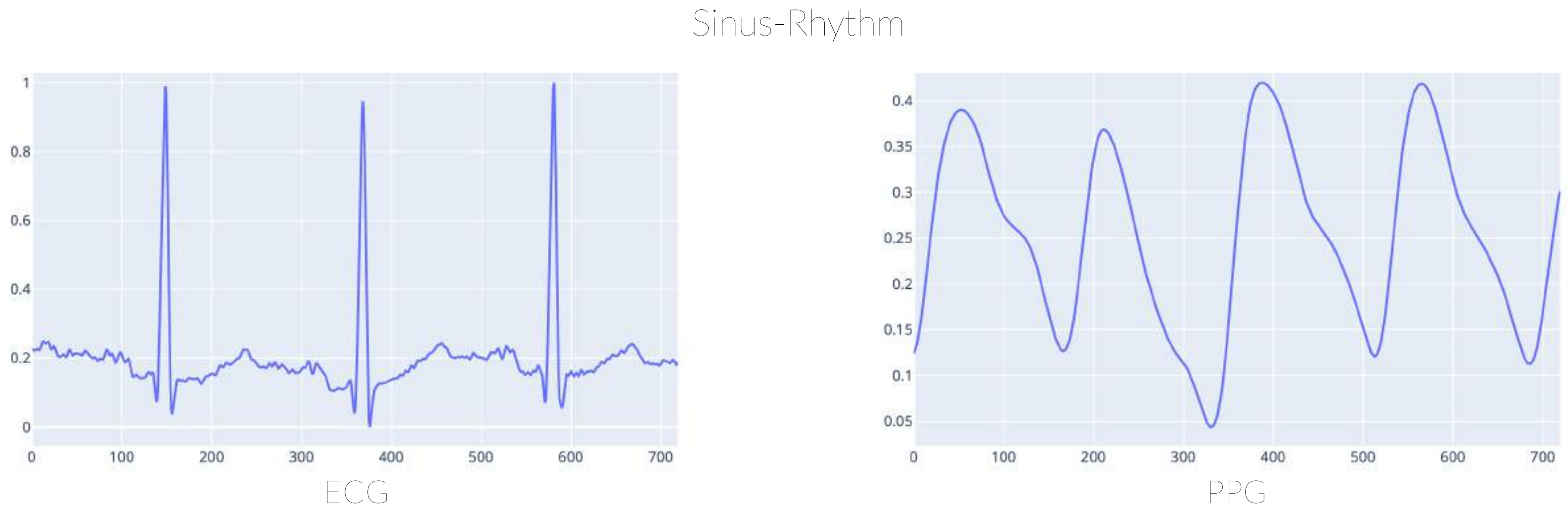
Ensemble of Multiple Binary Classifiers



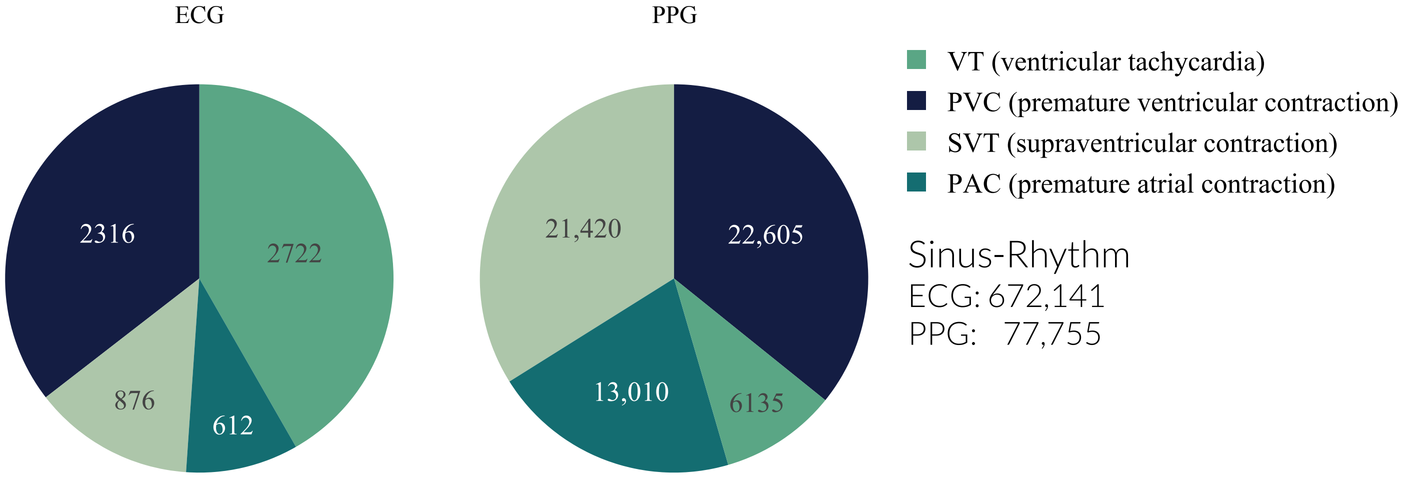
- division of the multiclass problem into subtasks
- each model performs a binary classification
- combined output carries out the classification
- one-vs-all combination



Data



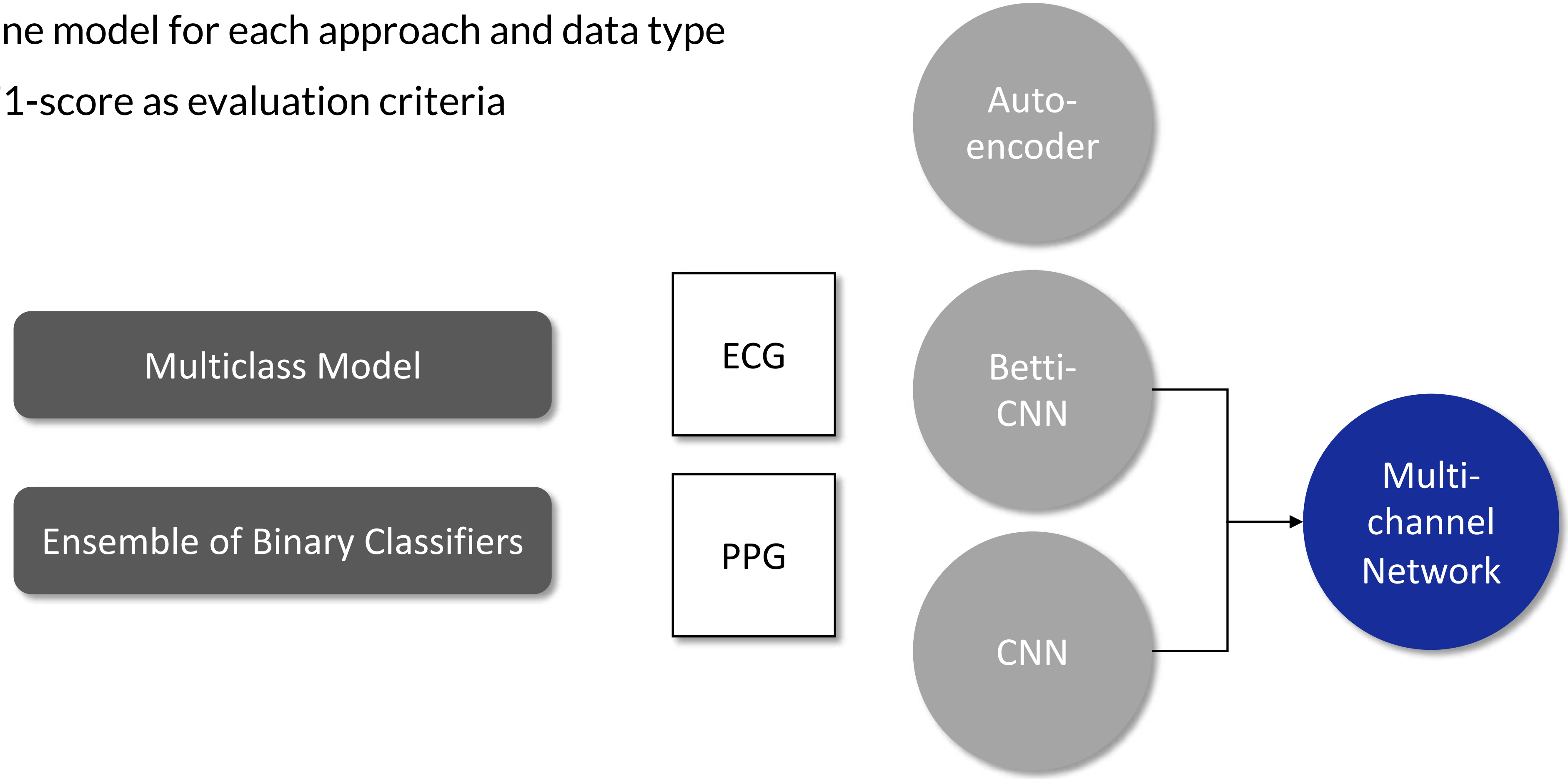
- data from different patients and different databases
- extraction of two-second long sequences
- inter-patient approach



Sinus-Rhythm
ECG: 672,141
PPG: 77,755

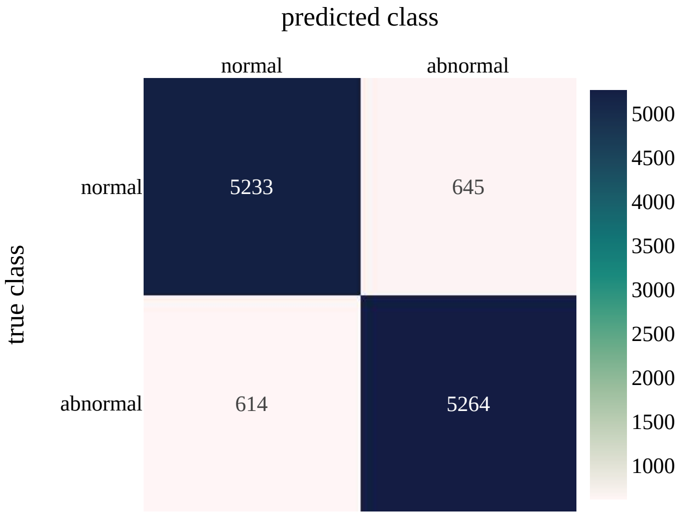
Results

- models are tested independently
- one model for each approach and data type
- F1-score as evaluation criteria

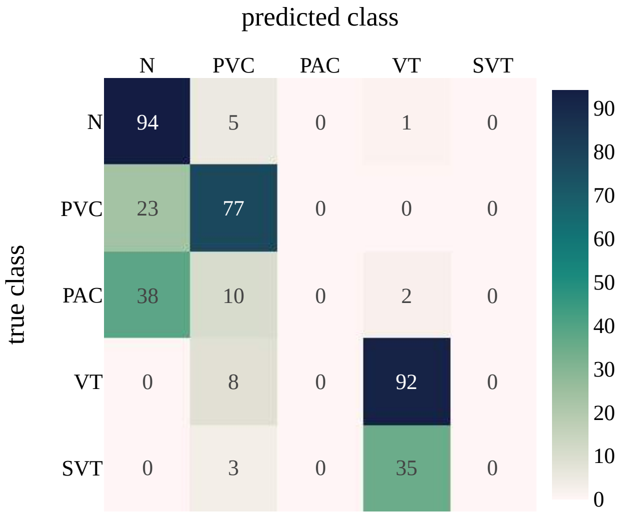


Results

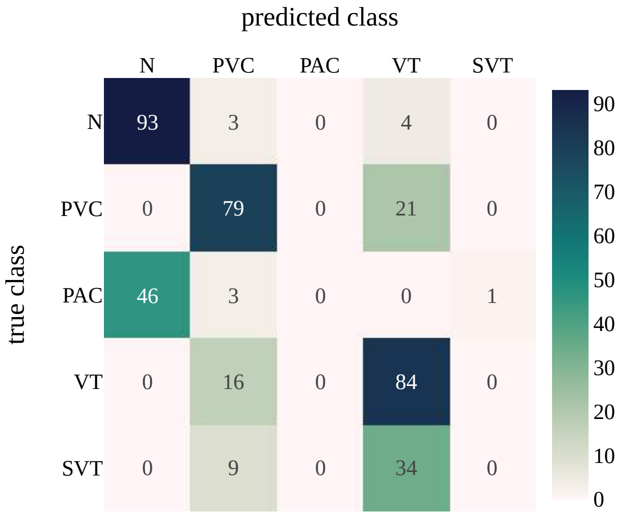
ECG



Autoencoder



Betti-CNN



CNN

	Autoencoder	Betti-CNN	CNN	Multichannel Network
ECG	89%	62%	56%	61%
PPG	65%	35%	7%	18%

F1-scores of each model in the multiclass model for each data type

Results

Ensemble of Binary Classifiers

ECG

Class	Betti-CNN	CNN	Number of Samples
sinus rhythm	91%	96%	>5,000,000
premature ventricular contraction	93%	92%	2,316
ventricular tachycardia	92%	89%	2,731
premature atrial contraction	66%	50%	612
supraventricular tachycardia	91%	88%	867

F1-scores of each model in the binary ensemble trained on ECG data for each class and the number of samples.

PPG

Model	Multiclass Approach	Binary Ensemble
Betti-CNN	35%	59%
CNN	7%	71%
Multichannel Model	18%	89%

Comparison of F1-score performance between the multiclass approach and the ensemble of binary classifiers.

Conclusion

improvement of the multiclass classification of cardiac arrhythmias in PPG signals

ensemble of multiple one-vs-all binary classifiers

F1-score of 89% for five classes on PPG data, outperforming other methods

advantages of ensemble approach:

- benchmark results with small model structures and less training data
- multiple labels per sequence
- practical for smart device applications

verification of CNN performance with larger training data and more complex structure

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