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Automatic Classification of 20 Different Types of Atrial Flutter Using 12-Lead ECG Signals: a Preliminary Computational Study

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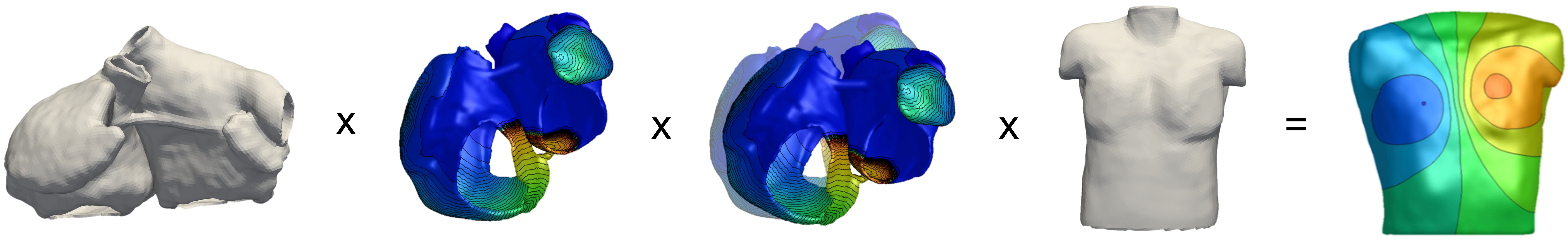
Motivation

So far, intracardiac catheterization is used to identify and treat atrial flutter (AFl) based on mapping performed prior to the ablation[1]. In this study, we investigated the possibility to automatically identify 20 different AFl mechanisms from features extracted from non-invasive cardiac signals (12-lead ECG). In a future clinical practice, the results of this work could robustly identify what type of AFl mechanism is ongoing using only 12-lead ECGs. This will allow the doctors to plan in advance the ablation procedure in the best possible way, focusing the need to invasively map the atria only in specific atrial regions, and thus saving time for the procedure.

Models & Methods

Simulated signals

8 atrial geometries — 19-20 flutter mechanisms — 2 atria orientations — 8 torso geometries — 2512 BSPM simulations



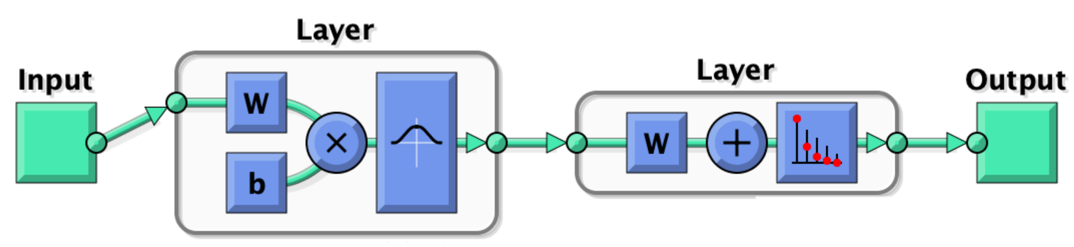
- Fast Marching simulations[2]
- Remodeled courtemanche action potential of atrial electrophysiology[3]
- Boundary element method (BEM) to solve the forward problem of electrocardiography
- Extraction of the 12-lead ECG from the BSPM

Data & Features

- 151 features were extracted from different domains (e.g., time, frequency, entropy).
- Dataset:
  - Train set 70%
  - Validation set 15%
  - Test set 15%
- Greedy forward feature selection and correlation analysis.

Classifiers

- Decision tree (183 splits; 5 features).
- K-nearest neighbor (cityblock distance; 5 neighbors; 27 features).
- Radial basis neural network (rbNN) (1 hidden layer; 1 softmax layer; 2240 neurons; 19 features).



Cumulative Matching Characteristic (CMC)

- Method that provides the accuracy value for the number of likely classes to be predicted in output. Number of classes of interest as output evaluated in this work = 2.

Results

Classifiers

- Accuracy for each classifier on the test set.

	Accuracy [%]
Decision Tree	80.23
K-nearest neighbour	84.52
rbNN	89.84

- Accuracy for the radial basis neural network classifier on the test set using the CMC.

	CMC Accuracy [%]
rbNN	98.66

P-wave duration

- P-wave duration is the most discriminative single feature.

	Accuracy [%]
rbNN: only P-wave duration	75.05
rbNN: without P-wave duration	34.78

Atria-torso geometries relevance

- Training of rbNN using all the geometries-1, and using the rest as test set.

Accuracy [%]	Atria	Torso
rbNN: test set	22.50	90.12
rbNN: test set + CMC	33.42	98.63

Conclusions

- The implemented classifiers can potentially identify different AFl mechanisms using the 12-lead ECG.
- P-wave duration is the most important feature.
- Atrial geometries play a fundamental role in the discrimination of different AFl, influencing the P-wave duration. Opposite for torso geometries.
- The results show the efficacy of the P-wave duration, meaning that it is different from case to case. But this feature is also highly dependent on the atria geometry and/or the atrial tissue conduction velocity (CV). So, this feature is not robust to new patients with completely different atria geometries and/or CV.

Outlook

- Other features can be studied to improve the classification performances.
- Some classes might be merged to define possible clinically relevant clusters. For example, macro groups of AFl (macroreentry, microreentry, etc), or common ablation procedures.
- Test of the algorithm on clinical data.
- More simulations changing the CV and more atrial geometries needed to produce more P-wave duration samples. This could help in making the classifier more robust to new subjects (better generalization).

Acknowledgment

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1. S. Bun, D. G. Latcu, F. Marchlinski, N. Saoudi, "Atrial flutter: more than just one of a kind." *European Heart Journal*, vol. 36, pp. 2356-2363, 2015. 2. T. Oesterlein, "Multichannel Analysis of Intracardiac Electrograms: Supporting Diagnosis and Treatment of Cardiac Arrhythmias.", PhD Thesis, pp. 114, 2016. 3. A. Loewe, "Modeling Human Atrial Patho-Electrophysiology From Ion Channels to ECG : Substrates, Pharmacology, Vulnerability, and P-Waves," \emph{KIT Scientific Publishing}, 2016.

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