B10

Magnetoelectric Sensor Systems for Cardiologic Applications

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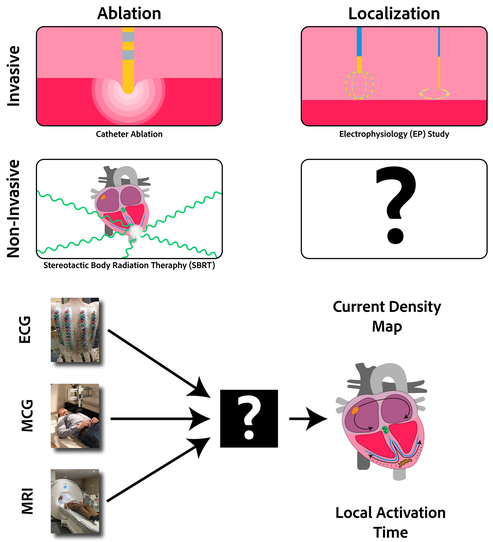
biomagnetic sensing SFB 1261

Motivation and Objectives

Non-invasive localization of arrhythmogenic tissue

- Treating cardiac arrhythmias requires precise substrate localization
- While non-invasive ablation procedures exist, non-invasive localization procedures are not established
- Two-fold benefits: Risk avoidance, reduced mapping barriers
- Challenge: Unknown parameters exceed available measurements
- Existing approaches: different design goals leading to significant drawbacks



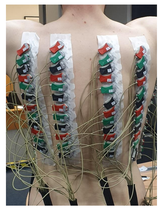
- Goal: development of algorithm with good scaling and interpretable results that does not require invasive training data

Results of the Second Funding Period

State-space system model and magnetic forward model

[B10-1, B10-11]

- Implementation of local voxel connectivity to reduce computational complexity
- Integration of first-order all-pass filters for variable and differentiable delay
- Inclusion of six substrate types with normal connectivity and varying propagation velocities
- Control input based on the dynamic O'Hara-Rudy model
- Forward simulation facilitated through a measurement matrix based on Biot-Savart's law



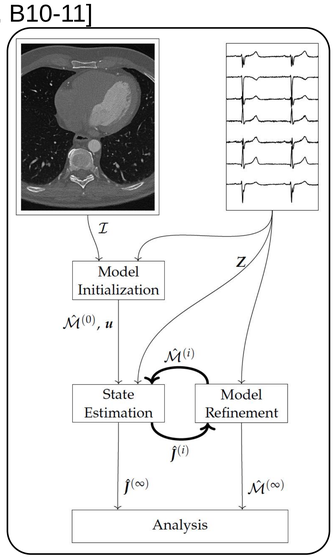
Kiel Cardio Database

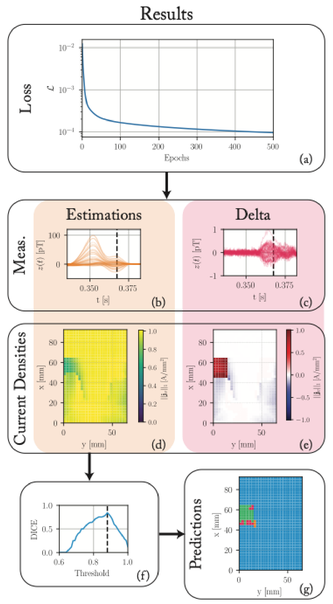
[B10-10]

- Open access MCG database of PhysioNet (8 healthy subjects)
- 144 channel ECG, 8 channel MCG

Current density estimation through nested optimization

[B10-1, B10-11]





- Simulative evaluation: 2D setup with 2.5mm voxel size, 2886 system states, 144 sensors
- DICE score: 0.84; recall: 0.77; precision 0.93
- Optimization for 2000 epochs (~1 hour)

green—true positive (TP)
blue—true negatives (TN)
orange—false positive (FP)
red—false negatives (FN)

Work Plan for Third Funding Period

Research methods

- Extension and refinement of the estimation algorithm through rigorous simulations and benchmarking
- Transition to the application of the algorithm to real-world data
- Involve patients in additional non-invasive measurements, pre- and post-operative
- Comparison of non-invasive approach with the gold standard of catheterization
- Long-term study of the 3D heart axis

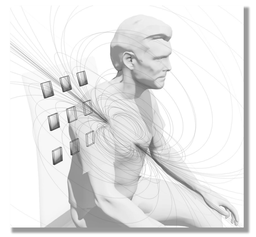
Work plan

WP1: Extension of Estimation Algorithm

- Inclusion of secondary and electrical currents
- Refinement of the system model for variable refractory periods
- Exploration of advanced optimization algorithms
- Extension of real-time capability using nested threads on multi-core hardware

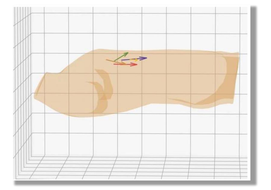
WP2: Evaluation of Clinical Relevance

- Shift of research focus from healthy subjects to patients
- Collection of corresponding sets of invasive and non-invasive measurements
- Open sharing of datasets by integrating them into the Kiel Cardio Database



WP3: Improvement of Measurement Setup

- Establishment of a 32-channel ME MCG system
- Improvement of ECG electrodes localization
- Implementation of flexible printed circuit boards as stripe electrodes



WP4: Non-invasive 3D Heart Axis Estimation

- Investigation of patient-specific 3D axis changes using magnetoelectric sensors

		2024		2025				2026				2027				2028	
		3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2
WP1 – Extension of Estimation Algorithm	Engineer (100%)																
	Med. doctor (25%)																
	Study nurse (25%)																
WP2 – Evaluation of Clinical Relevance	Engineer (100%)																
	Med. doctor (25%)																
	Study nurse (25%)																
WP3 – Improvement of Measurement Setup	Engineer (100%)																
	Med. doctor (25%)																
	Study nurse (25%)																
WP4 – Non-invasive 3D Heart Axis Estimation	Engineer (100%)																
	Med. doctor (25%)																
	Study nurse (25%)																

Collaborations

A1, A2, A4, A7, A9: Evaluate sensors for cardiologic applications and provide feedback for sensor development.

A8, A10: Include sensor models and findings in forward model.

A2: Development of flexible electrode setup.

B1, Z2: Work together on flexible electrodes, 32-channel MCG setup an 3D heart axis setup.

B2, B9, B11(N): Work together in same real-time framework. Use localization algorithms for patient body tracking.

Z1: Use fabricated sensor for measurement setups.

Z2: Use sensor characterizations in forward model.

Participation in focus groups

F3: Comparison of Sensor Concepts

F6: Biomedical Applications

Funds Requested

1 Doctoral researcher, 0.25 medical doctors, 0.25 study nurses, consumables: 48.5 k€

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