Closed-loop quantitative verification of rate-adaptive pacemakers

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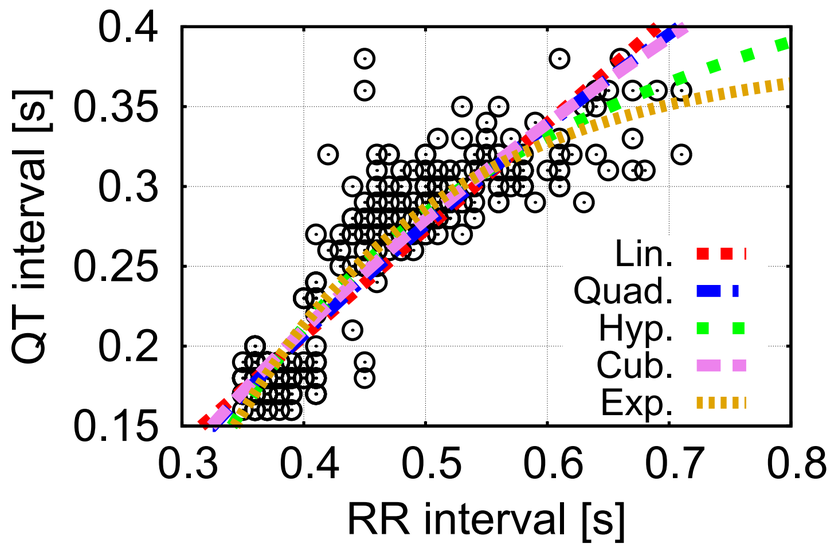
Abstract

- Cardiac pacemakers are electrical devices that treat arrhythmias delivering electrical stimuli to the patient heart
- **Rate-adaptation**: regulation of pacing rate according to patient's needs (e.g. increased pacing rate during exercise)
- Programming of rate-adaptation parameters depends on many patient-specific factors (age, lifestyle, tolerance to rapid pacing, …)
- Effective **personalisation** achievable only through extensive exercise testing: intolerable for a cardiac patient
- We introduce a data-driven and model-based approach for subject-specific verification of rate-adaptive pacemakers

Models and methods

- Design and implementation of fully **closed-loop model** of heart and pacemaker interactions
- Dual sensors rate-adaptive pacemaker: accelerometer + QT interval
- **Sensors blending**: combines quick but inaccurate accelerometer response to activity with accurate but slower QT response
- **Pacemaker personalisation**: achieved through estimation of subject-specific QT-RR regression laws
- Heart model personalisation performed from subject-specific ECG
- **Arrhythmias**: Modelling of atrio-ventricular (Wenckebach AV block) and atrial arrhythmias (atrial fibrillation)
- Quantitative model analysis using Cosmos tool for statistical model checking

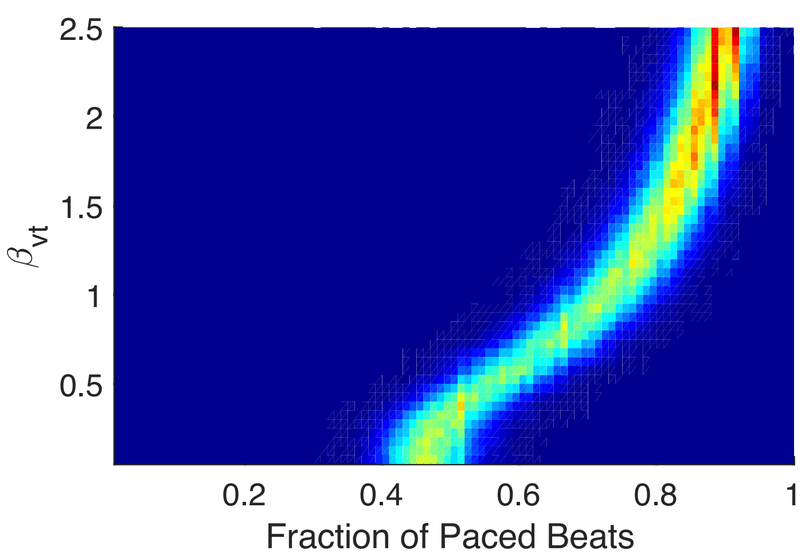
Pacemaker personalisation



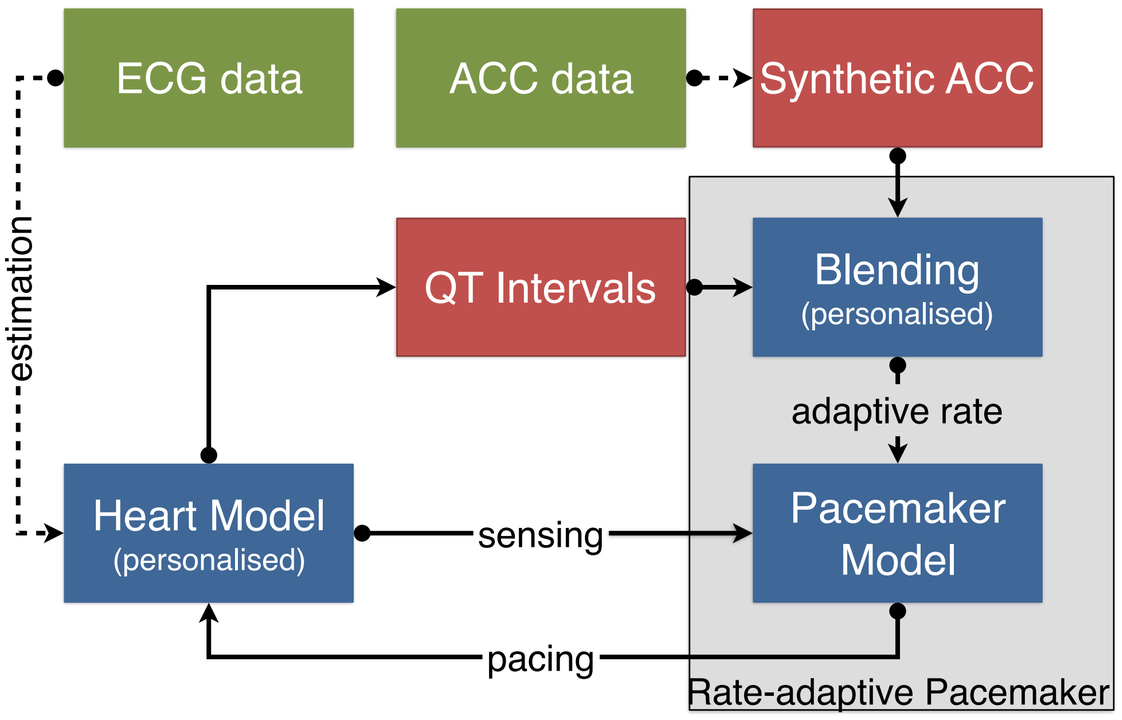
Results

- **Adequacy under exercise**: comparison of three pacing algorithms under ideal exercise curve and Bruce exercise testing protocol
- **Percentage of paced beats vs. AV block**: estimation of distribution of number of paced beats under increasing severity of AV block

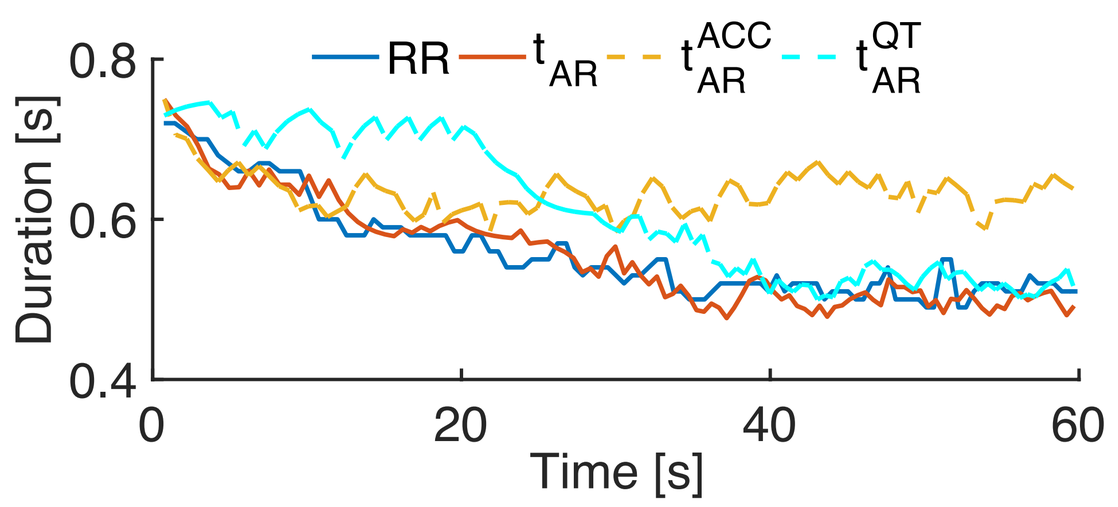
Percentage of paced beats vs. AV block



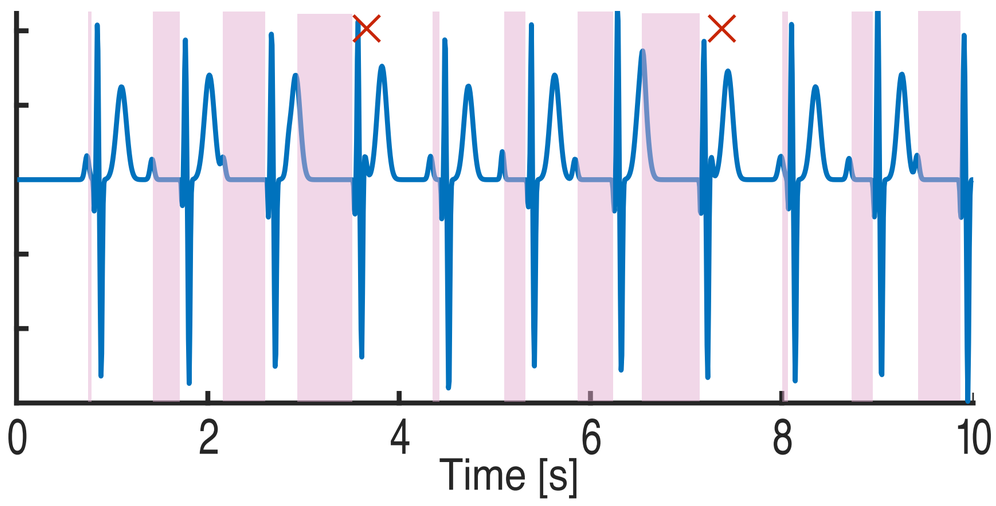
Closed-loop model



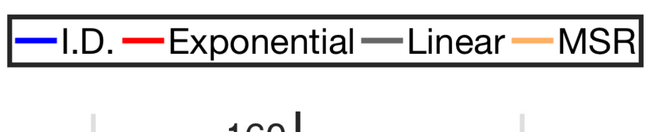
Sensors blending

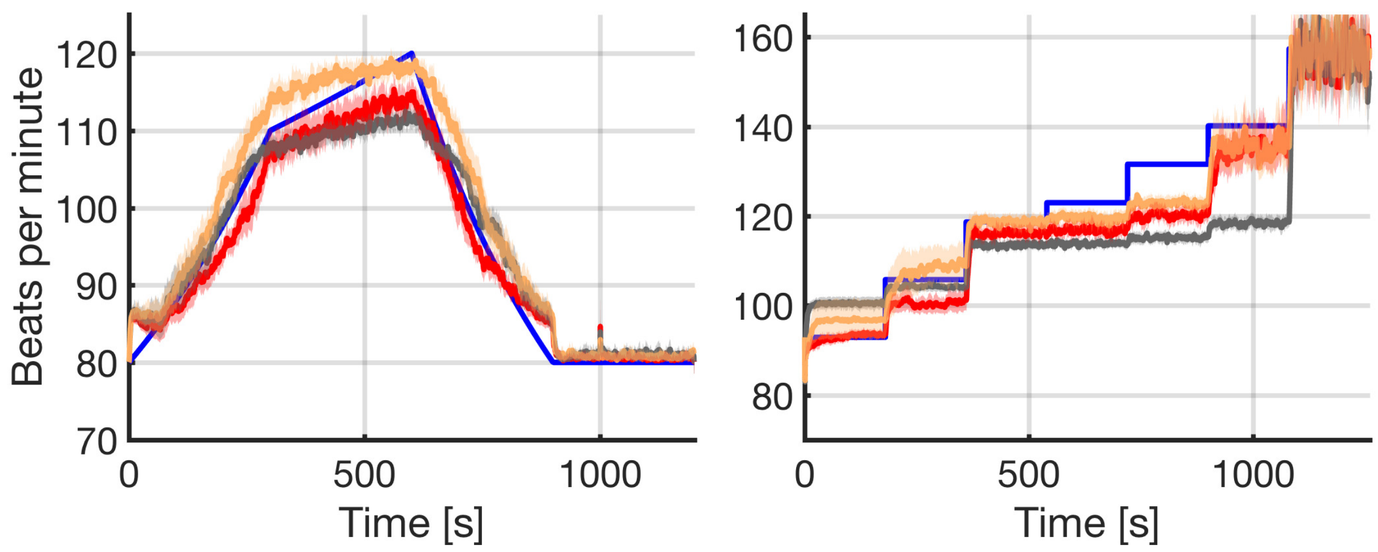


Arrhythmias modelling



Adequacy under exercise





Acknowledgments

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