Closed-loop quantitative verification of rate-adaptive pacemakers
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Abstract
• Cardiac pacemakers are electrical devices that treat arrhythmias by 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.

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.

Acknowledgments
This project has received funding from the EU’s Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 722022.