Introduction

- Electrocardiogram (ECG) acquired for
  - Patient monitoring
  - MRI acquisition synchronization with heart activity
- More and more applications need accurate ECG analysis during MRI:
  - High or Ultra-High field cardiac applications
  - Interventional MRI
  - Intra-Cardiac Electrophysiology guided by real-time MRI
  - Cardiac Stress-tests during MRI

Objective

Development of a technique for the suppression of the MHD effect and accurate analysis of ECG signal, especially during pathological ventricular repolarization.

Methods

- Data:
  - Artificial ECG signals with pathological ventricular repolarization
  - QT elongation
  - T wave inversion
  - Modeling of the MHD based on blood flow MRI measurements
  - Real noise data from the NSTDE

- Bayesian filtering, applied for denoising and source separation, derived from a set of equations, evolution (1) and observation (2):

\[
\theta_k = (\theta_{k-1} + \omega) \mod 2\pi
\]

\[
W_k = -\frac{\omega}{b^2} \sum_i \omega E_i \Delta \theta_{i,k-1} \cdot \alpha_{i,k-1} \cdot \beta_{i,k-1} + W_k + \eta W_k,
\]

\[
\psi_{i,k} = \psi_{i,k-1} + \epsilon_{i,k},
\]

with \( \psi_{i,k} \in \{\alpha_{i,k}, \beta_{i,k}, \epsilon_{i,k}\} \) and \( W_k \in \{P_k, Q_k, T_k, M_k\} \) and

\[
\theta_k = \theta_k + v_{1,k},
\]

\[
s_k = P_k + Q_k + T_k + M_k + v_{2,k},
\]

\[
s_k = M_k + \sum G (\epsilon_{i,k}, \Delta \theta_{i,k}, \beta_{i,k}) + v_{3,k},
\]

\[\delta \theta_k \text{ the angular position,}\]

\[\omega = 2\pi/RR \text{ the angular speed},\]

\[\delta \text{ the sampling period,}\]

\[\Delta \theta_{i,k-1} = (\theta_{i,k-1} - \epsilon_{i,k-1}),\]

\[G(a, b, c) = a \exp(-b^2)/2c,\]

\[s_k \text{ the ECG signal,}\]

\[\phi_k \text{ is an artificial piecewise linear phase signal,}\]

- P, Q, T and M represent the P wave, the QRS complex, the T wave and the MHD effect respectively.

\[
\alpha_{i,k}, \Delta \theta_{i,k}, \beta_{i,k}, \epsilon_{i,k}
\]

and \( \alpha_{m,k}, \Delta \theta_{m,k}, \beta_{m,k}, \epsilon_{m,k} \) those for the MHD effect.

- Automatic ECG classifications with ECGpuwave.

Discussion

- Limitations:
  - Time of convergence for the filter \( \Rightarrow \) missed transient events
  - Over-estimation of QT segment \( \Rightarrow \) use Bayesian filter for extracting fiducial points
  - Artificial data do not model changes in blood flow \( \Rightarrow \) application of the technique on real data (induced ischemia)

- Promising technique lays foundations for accurate ECG analysis in hostile environment such as during MRI scanning.

References


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