Utilization of a Computational Cardiac Electromechanics for Mechano Electric Feedback

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1 GOALS
- modelling the electromechanics of the myocardium
- generation of patient-specific heart models
- validation of the developed numerical schemes
- simulating arrhythmias and its termination
  (commpotio cordis and premature ventricular contraction)

2 CARDIAC ELECTROMECHANICS

coupled governing equations
- state variables
  \[ \{\psi(X, t), \phi(X, t), \mathcal{L}_e(X, t), \mathcal{L}_f(X, t)\} \]
- quasi-static equilibrium
  \[ J \text{ div } [J^{-1} \tau] + B = 0 \]
- electrical equilibrium
  \[ \phi = J \text{ div } [J^{-1} \mathbf{q}] + \mathbf{F} \phi \]
- rheology for electro-visco-elasticity of the myocardium

Aliev & Panfilov model for excitation of the myocardium

ionic source (electrically normalized)

\[ f^e = f^e_c(b, \phi) + f^e_p(g, F, \phi) \]

purely electrical part

\[ f^e = c_0 \phi (\phi - \alpha) (1 - \phi) - r \phi \]

\[ j = \{ \gamma + \frac{\mu_1}{\mu_2 - \sigma} \} \big[ -r - c_0 (\phi - b - 1) \big] \]

mechano electric feedback

\[ \mathbf{F}_e = \mathbf{G}_e (\lambda e - 1) (\phi_e - \phi) \]

hemodynamics of the ventricles
- blood pressure is modelled as a function of the deformation state (the ventricle cavity volume \( V \))
- windkessel model for the ejection phase

\[ \dot{p}_e = \frac{1}{C_{up}} (1 + \frac{R_i}{R_p}) g + R_e \phi - \frac{\dot{q}}{C_{vol} R_p} \quad q := -V \]
- filling and isovolumetric phases

\[ \dot{p}_e = \ddot{\lambda} (1 - \theta) \quad \theta := \frac{V}{V_0} \]

3 PATIENT SPECIFIC HEART GEOMETRY

generation of patient specific heart geometry

4 NUMERICAL EXAMPLES

commpotio cordis and precordial thump

premature ventricular contraction induced by hemodynamic disturbance

normal healthy cycle

the cycle with reversed T-wave

premature ventricular contraction

hemodynamic disturbance

remature ventricular contraction