DYNAMIC MODELING OF THE HUMAN HEART

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Sudden cardiac death, mostly caused by ventricular fibrillation, is responsible for at least five million deaths in the world each year. Despite several years of research, the responsible mechanisms for ventricular fibrillation are not yet well understood.

As most simulation studies are limited to planar simulations, the responsible mechanisms for the spatial phenomenon of ventricular fibrillations are not elucidated by far. It would be important to know how the most important heart parameters, such as the heart's size, geometry, mechanical and electrical state, tissue homogeneity and fiber structure, affect the development of ventricular fibrillation. The main difficulty in the development of a quantitatively accurate simulation of an entire three-dimensional human heart consists in the limited number of heart models, and the rapidly varying, highly localized fronts produced within the human heart muscle. Moreover, in pathological cases, the most relevant parameters of the conduction properties are significantly altered and they can produce spiral, self-inducing depolarization waves, which often transform into ventricular fibrillation. These regional alterations of the conduction properties are mostly patient-specific. To approach towards the solution of these problems, a complex modeling of the heart is necessary.

This book focuses on the adaptive ECG analysis and heart modeling. In the first chapter, a detailed ECG processing method is presented, which uses an iterative filtering and parameter estimation technique to obtain the aimed results. This algorithm is capable of properly adapting itself to patient-specific demands. Instead of the direct or transformation based processing methods, which cannot cover the uncommon waveforms even if using large sample databases, this feature-specific ECG estimation method can handle almost all perturbed waveforms. The signal estimation and efficient compression processes are highly correlated by the a priori determined medical parameters. The advanced distortion analysis allows to adaptively modify the compression rate, assuring a predefined quality of the biological parameters.

In the second chapter a dynamic heart model is presented, which is capable OF simulate almost all important pathological cases. The depolarization waveform is simulated at a dynamically, locally and temporally variable resolution that yields a fast simulation, keeping the estimation error at a reasonable level. The adaptive mesh refinement algorithm establishes the proper local resolution based on the first derivative of the intracellular potential. The whole method is highly parallelized, so video cards can efficiently perform the bulk of the calculation.

In the third chapter the simultaneous processing of the ECG signal and echocardiography image sequence determines the latent connection between the heart's electrical and mechanical properties. This connection stands at the basis of the electro-mechanical model of the heart. The massive amount of a priori medical information can be used to determine the spatial coordinates of the heart walls. Using a time-dependent surface model, the 4D model of the heart can be determined. This spatio-temporal model was determined for normal and ectopic beats.

In the fourth chapter an advanced accessory pathway localization method is presented using the standard 12-lead ECG record. Although the published localization methods yield an almost 90% recognition rate, the weak points of the Arruda localization method can be exploited partially by the replacement of some decision criteria using a heart model simulation. The obtained clinical data evaluation supported the author's heart model based considerations.