Integrated Simulation of Pacemaker and Heart Model for Optimization of Rhythm Therapy

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Abstract: The heart is a muscular pump having four chambers; contraction of these chambers is managed by impulse sequence generated by sinoatrial node (SA) an area of specialized cardiac tissues in right atrium of the heart followed by conduction pathways. If conduction system is not functioning normally than pacemaker is used to generate an impulse which is analogous to the impulse signal generated by the cardiac tissues. There are problems in coordination while patient’s use pacemaker which lacks in providing needed therapy for heart contractions. In this paper, a simulation tool is proposed aims to improve effectiveness of therapy and pacemaker calibration by optimization of its pacing pulse. ECG (Electrocardiogram) is used as input diagnostic signal by pacemaker for tracking of pacing threshold. An integrated simulation of pacemaker and heart model using VISSIM software is proposed to adapt the pacemaker to patient’s specific and changing needs with an algorithm to enhance the synchronization and optimization of the pacing pulses delivered to heart.

Keywords: Pacemaker, Heart, Simulation, VISSIM, Optimization, Pacemaker, Pacing pulse

I. INTRODUCTION
A pacemaker is an electronic device for heart patients suffering from arrhythmias. Pacemakers monitor intrinsic ECG to see if the heart is beating too slowly or pause too long between beat the heart to beat than pacemaker delivers pulses i.e. Atrial and ventricular pacing pulses for heart’s contraction.

A. Cardiac Conduction System
The cardiac action potential arises from a group of specialized cells, the sinoatrial node. This action potential passes further to Atrioventricular node and purkinje fibers resulting in contraction of atria and ventricle for pumping blood in and out of heart.

![Figure1. Showing Action potential leading to muscle contraction](image1.png)

B. Electrocardiogram
It is a vital rhythmically repeating bio-signal synchronized by the function of heart represented by P, QRS &T waves. The shape, polarity and timing of the signal can be used to evaluate heart functions. So, due to its diagnostic feature it is used by pacemaker to correct the heart rhythm. The intrinsic electrical activity of the heart is sensed by electrodes on the pacemaker leads placed on heart connected to pacemaker.ECG is an extrinsic signal recorded from surface on body with leads.

![Figure2. Electrocardiogram with Intervals shown](image2.png)

C. Pacemaker issues
There are various pacing problems with pacemaker therapy such as sensing failure, capture failure, dislocation of leads etc. failure to capture event which arises due to changes in pacing threshold makes the pacing pulse...
generated of inadequate strength and inefficient to contract the cardiac muscle.

![Pacemaker diagram](image)

**Figure 3.** Diagram showing Pacemaker leads placed on Heart

In order to ensure the correct therapy the pacemaker need to responds appropriately to changing conditions.

II. LITERATURE REVIEW

Adaption of pacemaker by patients changing needs utilizing various ECG features extraction algorithm and pacemaker modeling is demonstrated by various approaches emphasizing on better therapy and battery saving. In presented paper [1] verification model of pacemaker and heart is demonstrated emphasizing on closed loop interaction of heart with pacemaker. In paper [2], an algorithm to analyze the ECG signals is developed helping in delivering pulses during electroporation based treatment. Further, paper [3] presented a model of pacemaker with rate adaptive feature using ECG’s QT interval. In [4] presented an approach of automatically detecting and adapting features like rate response, mode switching and AV interval by pacemaker with algorithm.[5] presented an algorithm for evaluation of pacemaker therapy and functional testing of pacemaker software.

III. PROPOSED SYSTEM

Aim of this paper is to develop an integrated simulation of heart and pacemaker model using VISSIM software to optimize the pacemaker pacing function and enhance quality of therapy given to patient by tracking changes in threshold. A pacing system must be able to confirm capture and automatically adjust its output pacing pulse to ensure adaptability to patient needs. The project aims to develop a simulated system by integrating heart and pacemaker model to improve efficiency of pacing pulse generated by pacemaker. The proposed system consists of heart model and pacemaker model developed by VISSIM software which is a visual block diagram language for simulation of dynamic system and model based design of embedded systems in less time with easy visual blocks instead of hard mathematical equations. Pacing threshold tracking and optimizing output pacing pulse is the aim to achieve. Pulse width and duration parameters are varied to make appropriate delivery of pulse to heart for contractions.

IV. METHODOLOGY

The methodology for proposed system consists of heart model and pacemaker model developed in VISSIM environment and integrate the two models to provide optimized pacing pulse. ECG signal from Physionet database is used as input in ECG based heart model. Detected changes in pacing threshold is input to controller where parameters current and duration of pacing pulse is varied accordingly by optimization algorithm resulting in optimized pacing pulse thus improving therapy efficiency. Improvements in therapy can be observed.

A. Software Implementation

![Proposed Block Diagram](image)

**Figure 4.** Proposed Block Diagram of Integrated Heart and Pacemaker Model

B. Proposed system algorithm

![Pacing Pulse Optimization Flowchart](image)

**Figure 5.** The Proposed system for Pacing Pulse Optimization
V. CONCLUSION

After completion of proposed work an integrated simulation of pacemaker and heart model is developed using VISSIM software providing a common environment for realistic simulation. The model is able to simulate heart conditions of patient using Physionet ECG database in dual chamber pacemaker mode. The control algorithm helps in optimizing the therapy i.e. pacing pulse given by pacemaker for heart contractions using less energy. Quality of therapy is easily verified by model by observing the cardiac output. So, the simulation save time during follow-up and optimizes pacing outputs.

REFERENCES


