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Design of Advanced Control Strategies for Cardiovascular System

V. Jeyanth Fedal Castro[a] and R. Malathi[b*]

[a]*Ph.D Research Scholar, Department of EIE, Annamalai University, Chidambaram, Tamil Nadu India*
[b*]Professor, Department of EIE, Annamalai University, Chidambaram, Tamil Nadu India

Abstract

Cardiovascular diseases are chief causes of anguish and mortality in the developed countries. Bio-medical engineering deals with the application of various approaches of engineering in the field of medicine and biology mainly for health care purposes thereby improving patient's quality of life. Out of the various techniques, the important focus is to develop a reliable and optimized technique for simulation of electric activity of heart. In an effort to make such a technique this work describes the design of a control system for regulating the Heart Rate (HR) for pacemaker in an efficient way. The overall control system to be developed, in this work is considered to be composed of cardiovascular system duly triggered by an intelligent pacemaker system as operated in a closed loop manner with unity negative gain in the feedback path. A conventional controller based on Proportional, Integral and Derivative (PID) is designed with the help of Zeigler-Nichols, Neural controller and Adaptive control schemes. The simulations have been carried out using MATLAB/SIMULINK. By the way of comparative study of simulated results of different control techniques it is found that the overall response of adaptive controller is better than the conventional PID controller.

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Keywords: – Cardiovascular, Pace Maker, Neuro controller, Neuro-fuzzy controller, Neuro PI and Neuro PID controller.

* Corresponding author. Tel. +91 9443879055.

E-mail address: vsmalu@gmail.com

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1 INTRODUCTION

Every system can be monitored by measuring some physical parameters from the system. The physical parameters may be electrical, mechanical or physical, etc. In the same manner each body parts generate their own signals and that can be used to monitor the functioning of the body organ. Most of the signals are electric in nature and called as bioelectric signal. Bioelectric signals are basically ionic voltages produced as a result of electrochemical activity of certain special types of cell. These natural bioelectric signals can be measured with the help of suitable sensors and results can be displayed to aid the physician in diagnosis. Among various physiological signals, cardio electrical signal, namely Electro Cardio Gram. Heart rate (HR) can be measured by calculating R-R interval of ECG. Normally rhythm of heart is synchronized by natural pacemaker of heart i.e. SA node. If there is any problem in conduction system of heart, a pacemaker is used. It applies an electrical impulse once it detects any ambiguity in the HR which may occur due to changes in electrical activity of the heart.

In the recent years several researchers have developed the controller system to bring working of heart to normal condition. S. C. Biswas*et al.* proposed a mathematical model of cardiovascular system using transfer function method [1]. Inbar *et al.* designed a closed loop pacemaker by using PI (proportional and integral) controller for regulating the mixing venous oxygen saturation level [2]. The performance of controller was demonstrated through its computer simulation. Sugiura *et al.* used a fuzzy approach to control HR using an artificial cardiac pacemaker regulated by respiratory rate and temperature. It was concluded from the results that the fuzzy method is well suited for the application [3]. Shin *et al.* proposed a neuro-fuzzy controller to study the rate adaptive pacemaker by motion and respiration. It is observed that the neuro-fuzzy inferred HR is more accurate than the one using normal fuzzy table look-up method [4]. Wojtasik, *et al.* also designed a fuzzy logic controller for rate-adaptive heart pacemaker [5]. The several authors have designed a family of fuzzy logic controllers for rate-adaptive cardiac pacemakers. The implemented algorithm offers good adaptation to the change in HR according to physiological needs of the patient and easy personalization. Several other researchers have also reported different algorithms for cardiac pacing [6-9]. *In* September 2003, *A. Ferro, C. Duilio, M. Santomauro, and A. Cuocolo*,[5] studied the role of heart rate on cardiac output (CO) at rest and during walk test in patients with dual-chamber pacemaker and depressed or normal left ventricular (LV) function. The importance is to the medical data sets for preset/desired heartrate profile as the reference input signal to our model. *In* May/June 2006*, S. A. P. Haddad, R. P. M. Houben, and W. A. Serdijin*, [4] presented a brief overview of the history and development of circuit designs applied in pacemakers, the most important advantage of their work was to show the electrical operation of the heart, the history and development of cardiac pacing systems and some new features in modern pacemakers. Fuzzy Controllers for Dual-Sensor Pacing Systems would provide better tracking accuracy.

2. PACEMAKER

A pacemaker is a device that generates electrical pulses and delivers them to the muscles of the heart (myocardium), in such a way as to cause those muscles to contract and the heart to beat. It is used to treat heart rhythms that are too slow, fast, or of any other irregularity. Figure 1 illustrates the implantation of a pacemaker in a human body. A pacemaker helps a person who has an abnormal heart rhythm resume a more active lifestyle. Broadly pacemaker has two functional units: first is "sensing circuit" by which it senses the patient‟s HR and second is "output circuit" through which it sends out electrical signals to heart muscles. This electrical signal is used to control the HR of the patient. Normally, small electrical pulses produced by a pacemaker can sustain a regular heartbeat. In case of deadly cardiac abnormalities, the pacemaker has to be adjusted to generate compulsive strong pulses assisting a patient to return to normal heartbeat [12].