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Intelligent Heart Rate Controller using Fractional Order PID Controller Tuned by Particle Swarm Optimization for Pacemaker

Imran Beg[1], Md. Sanawer Alam[2]

[1]Azad Institute of Engineering & Technology, Lucknow, Azadpuram Post: Chandrawal Via Bangla Bazar & Bijnour Near CRPF Camp, Lucknow

[2]Azad Institute of Engineering & Technology, Lucknow

Abstract: ***Every heart patient needs to regulate heart rate efficiently and robustly for providing life saving activity to their heart in a dynamic atmosphere. Several controller design came like proportional Integral derivative (PID) and Fuzzy Logic Controllers(FLC), but each of them were having some restrictions against the dynamic environment of the heart rate. Fractional order controllers that are defined by fractional order differential equation which provide the fine tuning of the control parameter to achieve the desired robustness and efficiency. In this work an efficient and robust fractional order PID controller is designed based on Particle swarm optimization tuning method. The stable FOPID controller overcome PID controllers with different tuning method including Fuzzy Logic Control in term of rise time, Percent, overshoot and settling time. The FOPID controller designed in this work is limited by tuning of different parameters like K_P, K_D, K_I, λ, δ. More efficient design can be obtained by using different optimization techniques such as particle swarm optimization intelligence or genetic algorithm tuning method which can offer an optimal control to cardiac pacemaker.***

Keywords: FOPID controller, cardiac pacemaker, PID controller, PSO .

1. Introduction

Heart diseases are one of the major cause of death among various people in different part of the world [14]. The technological advancement has been taking place in the field of cardiovascular system since the introduction of cardiac pacemaker curing several heart discrepancies.

Medical gadget (i.e. pacemaker) implants into body the body of any patient suffering from heart disease. Actually the pacemaker can be placed on the surface of the heart to stimulate the different chamber to pump the blood. The pacemaker sends the electrical pulses of suitable duration to control the abnormal heart beat caused by arrhythmias.

2. FOPID Controller

Robust dynamic control system designs are required to achieve better efficiency of the cardiac pacemaker. Many of the scientists have given various control system designs for intelligent pacemaker that uses fractional order PID controller that out performed PID controller on the basis of various index such as percent overshoot, rise time, and settling time for the step input of the heart [13]. The previous PID controller was not very optimal to provide the desired control strategies. This is because of using constant control parameter in feedback while active research progress in making the PID design more and more suitable and challenges will continue to obtain the best performance parameter such as percent overshoot, rise time, settling time [6].

Fractional order control is the general form of previously used controller or control scheme to non-integer orders. Fractional order control application are receiving more and more interest of the researcher since it provides more tuning parameters so offering more adjustable time and frequency response of the control system hence providing the robust performance. The advantage of fractional order controller is to provide more flexibility and insight in control design. And hence providing the path for designing the robust control system [6,13]. With the help of strong mathematical theory involving fractional calculus and fractional order differential equation, the robust design of FOPID can be achieved for better performances than ordinary PID controller.

The below mentioned section will give the brief description of FOPID controller design. The general transfer function of a PID controller $C(s)_{PID}$ can be described by:

$$C(s)_{PID} = K_P\,[1 + 1/T_I\,s + T_D\,s] \quad \ldots\ldots\ldots\ldots\ldots\ldots(A)$$

where,

K_P = proportional constant;
T_I = is integral constant; and
T_D = derivative constant.

The FOPID controller modifies the transfer function with non-integer orders for the integral and derivative terms as below:

$$C(s)_{FOPID} = K_P + K_I\,s^{-\lambda} + K_D\,s^{\delta} \quad \ldots\ldots\ldots(B)$$

Where, K_I is an integral constant, K_D is a derivative constant, and λ, δ are positive real number for integrator and differentiator respectively.

Hence when $\lambda=\delta=1$; the transfer function

$$C(s)_{FOPID}=C(s)_{PID} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(C)$$

Hence, with more number of tuning parameters more flexibility to the controller design can be added resulting in the improvement to the efficiency of the controller. In this work the another aim is to design and execute a FOPID controller based on the particle swarm optimization method for pacemaker design previously published in [6]. The author also compare the performance of the new FOPID controller with some of the previously used controller with PID and FLC based on percent overshoot, settling time(t_s) and rise time (t_r) for the step variations of the heart rate.

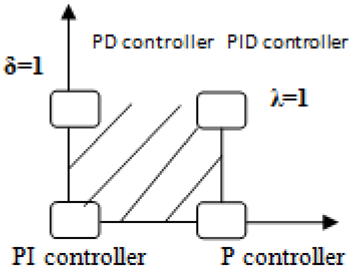
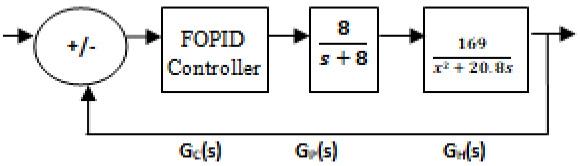


Figure 1

Given below the control structure for cardiac Pacemaker with unity negative feedback that was implemented in [2] is shown in fig. 2. Here $G_H(s)$, $G_P(s)$, and $G_C(s)$ are the transfer function of the heart, Pacemaker, and of the FOPID controller respectively. Also R(s) is the desired heart rate and Y(s) is the actual heart rate from the closed loop system.

In this work the previously designed PID controller has been mentioned it was based on Ziegler-Nichols(Z-N) method for comparison purpose. Other PID designs mentioned in [2] such as PID with Relay



Tuning and FLC design are directly compared with the performance of the FOPID controller for the performance values based on Rise time(T_r), settling time(T_s) and percent overshoot.

Though there are several method of tuning for Fractional order PID controller but in this work I have implemented Particle Swarm Optimization tuning method. Most of the tuning rule mainly focus on percent overshoot and rise time which should be lesser and lesser to obtain the robust and better controller and it will also improve the efficiency over fuzzy logic control. Hence PSO based tuning method is used to obtain the value of K_P, K_D, K_I to obtain the fractional order values for λ and δ that can produce desired result. In this paper all the parameter were tuned using MATLAB step by step.

3. Simulation Envirnment (FOMCON)

MATLAB/ Simulink software provides a suitable environment for all the simulation. The toolbox FOMCON is also a main tool for fractional order modeling and control. FOMCON is also used for design and implementation of the FOPID controller and display the response to various inputs. The controller was fed by various step input and sinusoidal variation in heart rate and final results were evaluated based on T_r, T_s, percent overshoot.

4. Result

Table 1

Rise Time: 0.01	Rise Time: 0.01	Rise Time: 0.01	Rise Time: 0.01
Settling Time:7.18	Settling Time: 8.83	Settling Time: 8.87	Settling Time: 8.85
Settling Min: 0.97	Settling Min: 0.86	Settling Min: 0.86	Settling Min: 0.85
Settling Max:1.02	Settling Max: 1.00	Settling Max: 1.00	Settling Max: 1.00
Overshoot: 2.60	Overshoot: 7.45	Overshoot: 7.37	Overshoot: 8.71

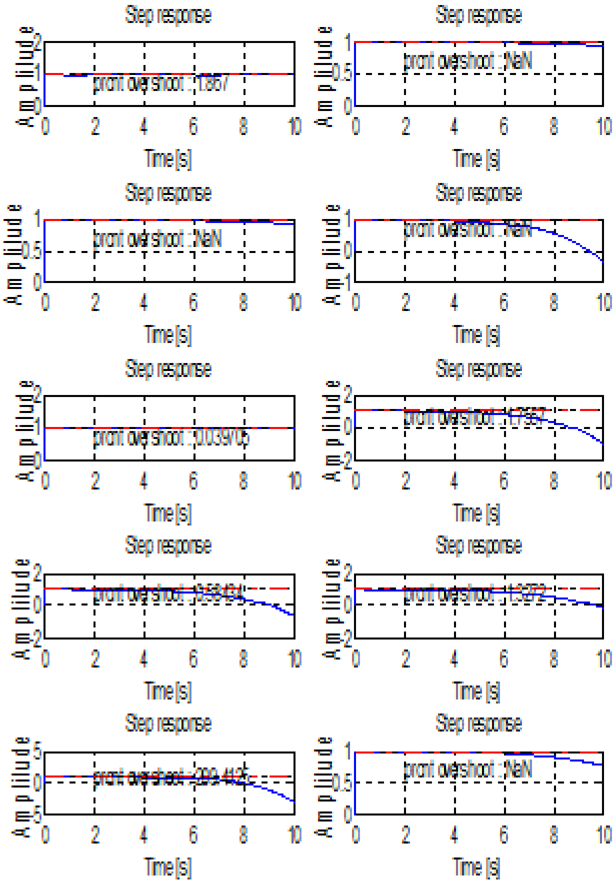


Figure 3

5. Conclusion

As we have seen that many controller method are now in trends and many optimization technique are there. But Proportional Integral Derivative controller are most widely used because of the effective result it produce. In this paper I have used Particle Swarm Optimization technique which is better than other techniques as it requires lesser time and effective results as shown in Fig.3. and the optimized result are shown in the table 1. In this way PID controller optimized the cardiac pacemaker more effectively saving more number of patients than before.

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Author Profile

Received the B.Tech degree in Electronics and Communication from Integral University Lucknow in 2013 and M.Tech degree in EIC from AKTU in 2017.