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State : Uttar Pradesh State Code 09

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Nandyal-518501
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State : Andhra Pradesh
State Code : 37
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Nandyal-518501
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State : Andhra Pradesh
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Authorised Signatory

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No.: BL/22-23/RCP/216

Dated 23-Aug-23

Balani Infotech Pvt. Ltd.

BALANI INFOTECH PRIVATE LIMITED
B-116, Sector-67, Noida - 201301
Distt. Gautam Budh Nagar
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Regd. Office: 119, Vinoba Puri, Lajpat Nagar Ii
New Delhi-110024
State Name : Uttar Pradesh, Code : 09
CIN: U72300DL2007PTC164136

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ID-15

by Vnbr Vnbr

Control Strategies for Blood Pressure Regulation in the Diabetic Patients Post Surgery

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Abstract. In modern years, most patients have diabetic, mean blood pressure and glucose associated health conditions, which can be treated by infusion of an antidote, although the dosage amount depends on the severity of the individual. The monitoring and regulation of the degree of dose is therefore critical in improving the health status of patients. This paper suggests that the dose of the medication infusion be regulated and managed on the basis of its amount. This is done by developing an integrated monitoring device that increases safety in less time and reduces healthcare costs. A statistical model of patient reaction to drugs is obtained in this article. The model comprises of five dimensions that ranges from patient to patient based on their drug response. The key purpose of the documentation is to enhance the efficiency and robustness of medication distribution activities. This Internal model control (IMC) based Proportional integral derivative (PI / PID) controller is introduced as a control system for patient distribution of drugs that will provide enhanced robustness and efficiency. The IMC driven PI / PID system has just one calibration parameter (λ), which is calibrated depending on the highest sensitivity (M_s). This method does not involve high complex mathematical equations.

Keywords: Internal model control, PID tuning; diabetic, glucose level, robust control, performance, antidote, MABP

1 Introduction

Mean arterial blood pressure (MABP) is one of the physiological factors to be controlled under appropriate limits during anesthesia, pre-and post-operative time. In general postoperative problems, particularly adult cardiac patients have elevated blood pressure, which escalate due to hypertension, notably after coronary artery bypass graft, valve replacement and pulmonary surgery [1]. It is important to monitor and regulate blood pressure (BP) to avoid bleeding from stitches in a patient's cardiac surgery to enhance healing. The correct MABP regulation medication is sodium nitroprusside (SNP), which has developed as an important vasodilator product [2]. Manual monitoring of MABP by hospital staff utilizing SNP is frequently stringent, meek and of low consistency due to differences in the reaction of patients to this substance regulation in blood pressure and regulated medication release over a prolonged period of time. Such factors also driven researchers to explore an automated management device that increases patient safety over a shorter amount of time and therefore decreases the incidence of disease. P and PI controllers do not deliver the necessary output during induction due to their slow response. This promotes the option of a strategy where the configuration of the device includes the individual as an essential part of the system. This solution is given by the Internal Model Control (IMC) framework, and the PID controller developed and calibrated using the IMC methodology should provide optimal efficiency, robustness and fast disturbance recovery. The IMC-based PID controller would also increase the consistency of medical treatment and managed distribution of medications [3-6]. The key objective of the proposed research is the design of the controller to achieve efficiency, disturbance recovery and robustness.

The efficiency of the IMC calibrated PID controller meets output requirements such as optimum peak overshoot, steady-state offset and durable stability. This approach records precise regulation of MABP as opposed to P and PI controls modified using traditional techniques.

2 Internal Model Control

The efficiency of the IMC calibrated PID controller meets output requirements such as optimum peak overshoot, steady-state offset and durable stability. This ap-proach records precise regulation of MABP as opposed to P and PI controls modified using traditional techniques.

Garcia and Morari coined the concept of internal model control; the process model is clearly an integral part of the controller [14]. The IMC system is shown in Fig. 1. Where, $Q(s)$ is the controller, $G_M(s)$ is the plant model and $G(s)$ is the actual plant/process.

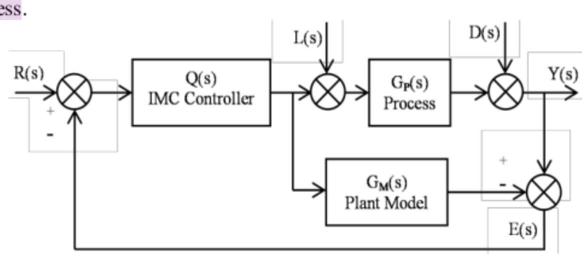

Fig. 1 Basic IMC structure.

The design of the IMC involves the following steps

2.1 Factorization

It includes factorizing the transfer function into invertible $G_{M-}(s)$ and non invertible parts $G_{M+}(s)$. The factor containing right hand poles zeros or time delays become the poles when the process model is inverted leading to internal stability. So this is non invertible part which has to be removed from the transfer function. Mathematically, it is given as Eq. (1)

$$G_M(\mathrm{s}) = G_{M-}(\mathrm{s})G_{M+}(\mathrm{s}) \tag{1}$$

2.2 Design of IMC Control

The IMC is the inverse of the invertible part of process model. It given as Eq.(2)

$$Q^{'}(s) = [G_{M-}(s)]^{-1}, \tag{2}$$

$Q^{'}(s)$ will be steady, yet may not be appropriate.

2.3 Adding Filter

Eq (3) is responsible for the generic transfer function of the system / controller. The value of the polynomial denominator will be almost equal to or greater than the numerator in order to render the system / controller semi-proper or worthy of physically understanding it.

$$T(s) = Z(s) / P(s) \tag{3}$$

In order to make the controller proper mathematically a low pass filter $F(s)$ is augmented to Eq. (2) and results in Eq. (4) and Eq. (5)

$$Q(s) = Q'(s) * F(s) \tag{4}$$

$$Q(s) = [G_{M-}(s)]^{-1} * F(s) \tag{5}$$

2.4 Low pass filter

The filter $F(s)$ described above is defined to have the form of Eq. (6) which represents a low pass filter.

$$F(s) = 1/(\lambda s + 1)^n \tag{6}$$

Where λ is the filter tuning parameter and n is the order of the process. The value of λ defines the performance and robustness of the controller. Maximum sensitivity M_S specification is an effective robustness measure and most recent inquisitive approach, which is defined by Eq. (7)

$$M_S = \max \left| \frac{1}{C(jw)G(jw)+1} \right| \tag{7}$$

The estimate of λ for IMC design of first order pulse dead time (FOPDT) system, is obtained by Eq. (8)

$$\lambda = \frac{1.508 - 0.451Ms}{1.45Ms - 1.508} T_i \tag{8}$$

A small value of M_S ensures high stability margin. So, the typical value of M_S is general adjusted to be in the range of 1.2 to 2.0

3 Design of the IMC Based PID Control

The purpose of this segment is to develop a basic feedback controller as an internal model system. The IMC rule for sundry modern cycle transfer functions is similar to the PID input system [14, 17], and The PID control algorithm is the basic input that has been developed for industrial processes due to its effortless and realistic applications. The regular IMC input equivalence is obtained by modifying Fig. 2. The standard feedback controller $G_{PID}(s)$ or $C(s)$ represented Fig. 2 and is the function of Plant model $G_M(s)$ and IMC controller $Q(s)$ shown in Eq. (9) is the IMC based PID relation, is approximated to the ideal PID controller of the form given by Eq. (10).

$$C(s) = Q(s) / \left[1 - G_M(s) Q(s)\right] \tag{9}$$

$$G_{PID}(s) = C(s) = K_P[T_i T_d s^2 + T_i s + 1 / T_i s] \tag{10}$$

In order to create a PID controller based on the IMC concept, $Q(s)$ is not made appropriate. The $Q(s)$ polynomial numerator of one order is rendered higher than the polynomial denominator with a derivative alternative and this is important for receiving the PID controller [8, 14, 18]. First order Padè approximation is used for the delay element θ of the plant model $G_M(s)$ to eliminate the behavior of predictive elements in the design of the PID controller. The first order Padè approximation is represented in Eq. (9) [14, 19].The PID controller tuned using IMC principle has only one adjusting term λ which provides both performance and robustness in spite of model uncertainties.

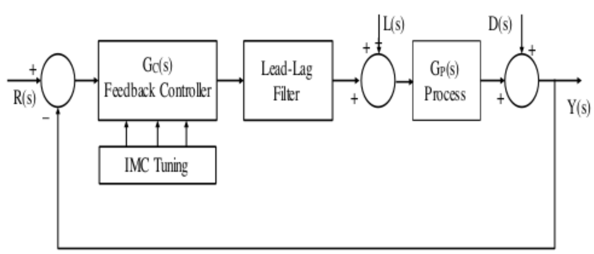

Fig. 2: Feedback Control Structure.

The following steps are used in the IMC-Based PID control system design:

- Find the IMC controller transfer function, which includes a filter to make it semi-proper
- Find the equivalent standard feedback controller using the transformation

$$C(s) = Q(s) / [1 - G_M(s) Q(s)] \quad (11)$$

- Compare the above equation with this PID controller from and find K_P, T_i and T_d.

$$G_{PID}(s) = C(s) = K_P[T_i T_d s^2 + T_i s + 1 / T_i s] \quad (12)$$

- Perform closed-loop simulation for both the perfect model case and case with model mismatch. Choose the desired value for λ as a trade-off between performance and robustness.

4 Simulation Results

The MATLAB simulations are carried out on different patients based on their drug sensitivity (Nominal, Sensitive and Insensitive). The performance of the IMC based PI/PID, IMC and

P controller to regulate the blood pressure by -30 mmHg to SNP drug infusion rate and error of different cases is carried out.

Case 1: Sensitive Patient

IMC-Based PID design for a First order plus dead time process of sensitive patient of Eq. (13) is

$$G_M(s) = -9e^{-20s} / (30s + 1) \quad (13)$$

Step 1: First order Pade' approximation

$$e^{-\theta s} = (1 - 0.5\theta s) / (1 + 0.5\theta s) \quad (14)$$

$$G_M(s) = -9(1 - 10s) / [(1 + 10s)(1 + 30s)] \quad (15)$$

Step 2: Factorising the sensitive patient model with Pade' approximation into invertible Eq. (16) and non-invertible portions Eq. (17)

$$G_{M-}(s) = -9 / [(1 + 10s)(1 + 30s)] \quad (16)$$

$$G_{M+}(s) = (1 - 10s) \quad (17)$$

Step 3: IMC controller is

$$Q(s)=\left[(30s+1)(1+10s)\right]/\left[-9(97.727s+1)\right] \quad (18)$$

Step 4 : Closed Loop Controller (PID) is

$$C(s)=\frac{(30s+1)(1+10s)/\left[-9(97.727s+1)\right]}{1-(1-10s)(97.727s+1)} \quad (19)$$

The K_P, T_i and T_d values are obtained by comparing Eq. (19) with the standard PID equation Eq. (10).

The simulation of the results of drug infusion rate, Blood pressure recovery and error of sensitive patient are represented in figures 3, 4 and 5 respectively.

Case 2 : Nominal Patient

The mathematical model of nominal patient is given by Eq. (20)

$$G_M(s)=-0.7143e^{-30s}\frac{\left(1+0.4e^{-45s}\right)}{(1+40s)} \quad (20)$$

Step 1: First order Pade' approximation of time delay element is Eq. (21)

$$e^{-30s}=\frac{(1-15s)}{(1+15s)},\ e^{-45s}=\frac{(1-22.5s)}{(1+22.5s)} \quad (21)$$

Step 2: Factorising the nominal patient model with Pade' approximation into invertible Eq. (22) and non-invertible portions Eq. (23)

$$G_{M-}(s)=\frac{-0.7143}{(1+15s)(1+40s)(1+22.5s)} \quad (22)$$

$$G_{M+}(s)=\frac{(1-15s)}{\left[(1+22.5s)+0.4(1-22.5s)\right]} \quad (23)$$

Step 3: The IMC controller is

$$Q(s)=\frac{(1+40s)(1+22.5s)(1+15s)}{-0.7143}*\frac{1}{(1+\lambda s)} \quad (24)$$

Where value of λ as 97.273, which is having range $\lambda > 0.2\tau$.

Step 4 : The closed loop controller (PID) is Eq. (25)

The simulation of the results of drug infusion rate, Blood pressure recovery and error of nominal patient are represented in figures 6, 7 and 8 respectively.

Case 3: Insensitive Patient

The mathematical representation of the dynamics of insensitive patient are depicted in Eq. (26)

$$C(s)=\frac{\frac{(1+40s)(1+22.5s)(1+15s)}{-0.7143}*\frac{1}{(1+\lambda s)}}{1-\left[\frac{(1+40s)(1+22.5s)(1+15s)}{-0.7143}*\frac{1}{(1+\lambda s)}*-0.7143e^{-30s}\frac{\left(1+0.4e^{-45s}\right)}{(1+40s)}\right]} \tag{25}$$

$$G_M(s)=-0.1786e^{-60s}\frac{\left(1+0.4e^{-75s}\right)}{(1+60s)} \tag{26}$$

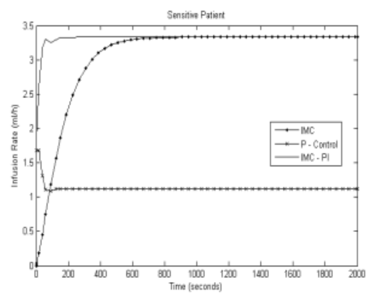

Fig. 3 SNP Drug infusion rate in sensitive patient

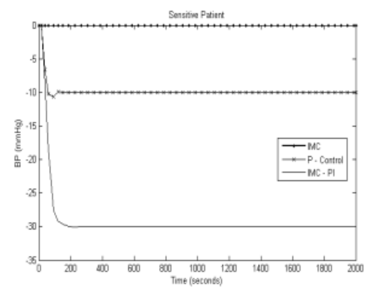

Fig. 4 Blood Pressure recovery with drug infusion in Sensitive patient

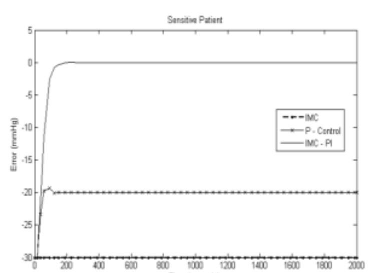

Fig. 5 Error in BP regulation in Sensitive patient

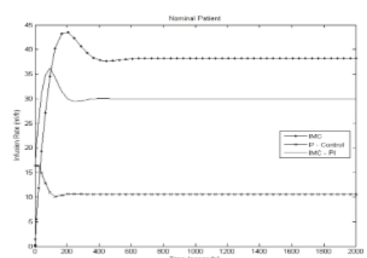

Fig. 6 SNP Drug infusion rate in Nominal patient

Step 1: First order Pade' approximation of time delay element is Eq. (27)

$$e^{-60s}=\frac{-30s+1}{30s+1},\ e^{-75s}=\frac{-37.5s+1}{37.5s+1} \tag{27}$$

Step 2: Factorising the nominal patient model with Pade' approximation into invertible Eq. (28) and non-invertible portions Eq. (29)

$$G_{M-}(s)=\frac{-0.1786}{(60s+1)(30s+1)(37.5s+1)} \tag{28}$$

$$G_{M+}(s)=(30s+1)(22.5s+1.4) \tag{29}$$

Step 3: The IMC controller is

$$Q(s)=\frac{(60s+1)(30s+1)(37.5s+1)}{-0.1786}\times\frac{1}{97.727s+1} \tag{30}$$

Step 4: The closed loop controller (PID) is

$$C(s)=\frac{(60(30s+1)s+1)(37.5s+1)}{\begin{pmatrix}-0.1786(97.727s+1)*\\ [1-[(-30s+1)[22.5s+1]]\end{pmatrix}} \tag{31}$$

The simulation of the results of drug infusion rate, Blood pressure recovery and error of insensitive patient are represented in Fig 9, 10 and 11 respectively.

Table 1: PID tuning values and IMC Controller

Patient	K_P	K_i	$Q(s)$
Sensitive	-0.0561	-0.0019	$\frac{(30s+1)}{(-879.543s-9)(1+97.7273s)}$
Insensitive	-1.3625	-0.0227	$\frac{(-60s+1)}{(17.4540s+0.1786)(1+97.7273s)}$
Nominal	-0.5450	-0.0136	$\frac{(-40s+1)}{(69.80s+1)(1+97.7273s)}$

The results described indicate that the PID controller tuned using IMC principle provides best possible performance for all nature of patients for faster recovery and regulation of Mean Arterial Blood Pressure in comparison to other controller methodologies considered. This helps the patient to recover faster post surgery and regulates MABP in elderly persons with hypertension. This technique can be extended to other applications relating to biomedical, medical electronics and assistive devices.

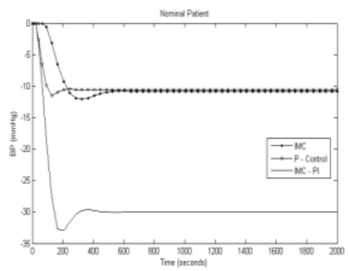

Fig. 7 Blood Pressure recovery with drug infusion in Nominal patient

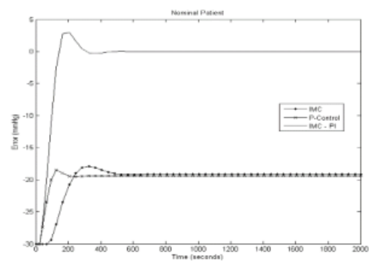

Fig. 8 Error in BP regulation in Nominal patient

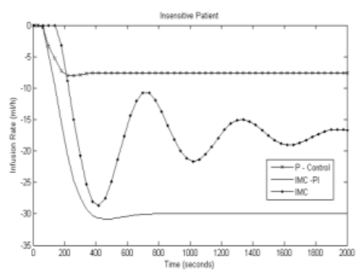

Fig. 9 SNP Drug infusion rate in Insensitive patient

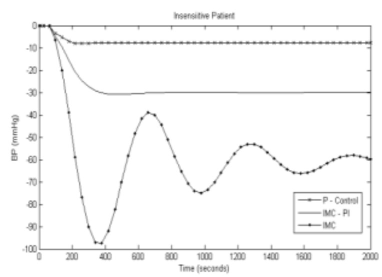

Fig. 10 Blood Pressure recovery with drug infusion in Nominal patient

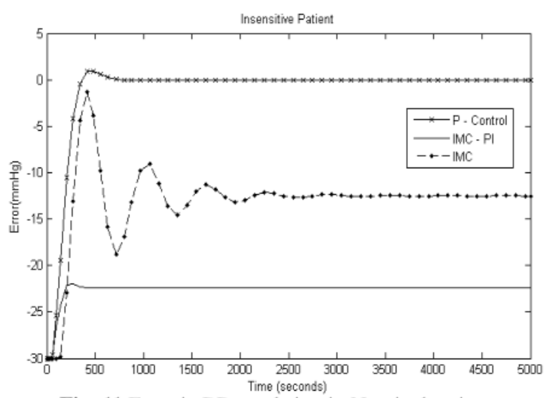

Fig. 11 Error in BP regulation in Nominal patient

5 Conclusion

Diabetes is a chronic disease, which causes serious health problems like kidney failure and heart stroke and recovery post-surgery is crucial in such patients. To control the mean arterial blood pressure a precise and accurate amount of external antidote SNP is needed to be injected into the human body. In this study, an IMC based PI/PID Controller is constructed for regulating the MABP and infusion of SNP in various nature of patients. The proposed methodology has provided faster recovery of MABP and precise control of SNP infusion, helping in faster recovery of patients.

References

1. Behbehani K, Cross RR. A controller for regulation of mean arterial blood pressure using optimum nitroprusside infusion rate. IEEE T Bio-med Eng. 1991; 38:513-21.
2. Frei C, Derighetti M, Morari M, Glattfelder A, Zbinden A. Improved regulation of mean arterial blood pressure during anesthesia through estimates of surgery effects. IEEE T Bio-med Eng. 2000; 47:1456-64.
3. Bajzer Ž, Maruši M, Vuk-Pavlovi S. Conceptual frameworks for mathematical modelling of tumor growth dynamics. Math Comput Model. 1996; 23:31-46.
4. Bergman R, Phillips L, Cobelli C. Physiologic evaluation of factors controlling glucose tolerance in man. J Clin Invest 1981; 68:1456-67.
5. Jeffrey AM., Xiaohua X, Craig IK. When to initiate HIV therapy: a control theoretic approach. IEEE T Bio-med Eng. 2003; 50:1213-20.
6. Hernandez L, Shankar R, Pajunen G. A microprocessor based drug infusion control system employing a model reference adaptive control algorithm to regulate blood pressure in I.C.U. patients. Proc IEEE Southeastcon. 1989; 1261-6.
7. Reves JG, Sheppard LC, Wallach R, Lell WA. Therapeutic uses of Sodium Nitroprusside and an automated method of administration. Int Anesthesiol Clin. 1978; 16:51-88.
8. Kovio AJ, Smollen VF, Barile RV. An automated drug có có Fig. 9. Comparison of various techniques using IMC design. 248 Biomed Eng Lett (2012) 2:240-248
9. Sheppard LC, Shotts JF, Robertson NF, Wallace FD, Kouchoukos NT. Computer controlled infusion of vasoactive drugs in post cardiac surgical patients. Conf Proc IEEE Eng Med Biol Soc. 1979; 280-4.
10. Slate JB, Sheppard LC, Rideout VC, Blackstone EH. A model for design of a blood pressure controller for hypertensive patients. Proc IEEE EMBS Conf. 1979; 867-72.
11. Slate JB, Sheppard LC. A model-based adaptive blood pressure controller. Proceedings of IFAC Symposium on Identification and System Parameter Estimation, Washington DC. 1982. 1982; 1437-42.
12. Martin JF, Schneider AM, Smith NT. Multiple-model adaptive control of blood pressure using sodium nitroprusside. IEEE Tran Bio-med Eng. 1987; BME-34:603-11.
13. Kaufman H, Roy R, Xu X. Model reference adaptive control of drug infusion rate. Automatica. 1984; 20:205-9.
14. Arnsparger JM. Adaptive control of blood pressure. IEEE T Bio-med Eng. 1983; BME-30:168-76.
15. Hahn J, Edison T, Edgar TF. Adaptive IMC control for drug infusion for biological systems. Control Eng Pract. 2002; 10:45-56.
16. Enbiya E, Hossain E, Mahieddine F. Performance of optimal IMC and PID Controllers for blood pressure control. IFMBE Proc. 2009; 24:89-94.

17. Morari M, Zafiriou E. Robust Process Control. Englewood Cliffs, NJ: Prentice-Hall; 1989.
18. Bequette BW. Process Control: Modeling, Design, and Simulation. Prentice-Hall, Inc., Upper Saddle River, New Jersey, USA; 2003.
19. Brosilow C, Joseph B. Techniques of Model-Based Control. Englewood Cliffs, NJ: Prentice-Hall; 2002.
20. Zhao Z, Liu Z, Zhang J. IMC-PID tuning method based on sensitivity specification for process with time-delay. J Cent S Univ Technol. 2011; 18:1153-60.
21. Hu W, Xiao G, Cai W. PID controller design based on twodegrees- of-freedom direct synthesis. Chinese Control Decis Conf. 2011; 629-34.
22. Parker RS, Doyle FJ. Control-relevant modelling in drug delivery. Adv Drug Deliver Rev. 2001; 48:211-28.
23. Shook DS, Mohtadi C, Shah SL. A control-relevant identification strategy for GPC. IEEE T Automat Contr. 1992; 37:975-80.
24. Mäkilä P, Partington JR, Gustafsson TK. Worst-case controlrelevant identification. Automatica. 1995; 31:1799-819.
25. Slate JB. Model-based design of a controller for infusion sodium nitroprusside during postsurgical hypertension. Ph.D. Thesis, Univ. Wisconsin-Madison. 1980.
26. Slate JB, Sheppard LC, Rideout VC, Blackstone EH. Closedloop nitroprusside infusion: Modelling and control theory for clinical application. Proc IEEE Int Symp Circ Syst. 1980; 482-8.
27. Jones RW, Tham MT. An undergraduate CACSD project: the control of mean arterial blood pressure during surgery. Int J Eng Sci. 2005; 21:1043-9.
28. Auer LM. Rodler H. Microprocessor control of drug infusion for automatic blood-pressure control. Med Biol Eng Comput. 1981; 19:171-4.
29. Saxena S, Hote YV. Advances in internal model control technique: A review and future prospects. IETE Technical Rev. 2012; 29:6:461-72.
30. Sahaj Saxena and Yogesh V. Hote A Simulation Study on Optimal IMC Based PI/PID Controller for Mean Arterial Blood Pressure: Biomed Eng Lett (2012) 2:240-248
31. B. Wayne Bequette Process control ,modeing, design and simulation prentice Hall international series in the physical chemical Engineering science, December 26, 2002
32. Panyam Vuppu, G.K.R., Makam Venkata, S. & Kodati, S. Robust Design of PID Controller Using IMC Technique for Integrating Process Based on Maximum Sensitivity. *J Control Autom Electr Syst* **26**, 466–475 (2015). https://doi.org/10.1007/s40313-015-0196-0
33. P.V. Gopi Krishna Rao, M.V. Subramanyam & K. Satyaprasad (2014) Design of internal model control-proportional integral derivative controller with improved filter for disturbance rejection, Systems Science & Control Engineering, 2:1, 583-592, DOI: 10.1080/21642583.2014.956372
34. R. Hanuma Naik, D.V. Ashok Kumar & P. V. Gopikrishna Rao (2020) Improved centralised control system for rejection of loop interaction in coupled tank system, Indian Chemical Engineer, 62:2, 118-137, DOI: 10.1080/00194506.2019.1647800

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