Control Theory and Informatics www.iiste.org
ISSN 2224-5774 (print) ISSN 2225-0492 (online)
Vol 2, No.3, 2012

Application of MRAC techniques to the PID Controller for nonlinear Magnetic Levitation system using Kalman filter

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Abstract

In this paper, an approach to model reference adaptive control based on pid Controller is proposed and analyzed for a magnetic levitation system class of nonlinear dynamical systems. The controller structure can employ a mit rule to compensate adaptively the nonlinearities in the plant. A stable controller- parameter adjustment mechanism, which is determined using the Kalman filter , is constructed using a pid controller-type updating law. The evaluation of control error in terms of the error is performed. the use of Kalmal Filter in conventional model reference adaptive control (MRAC) to control magnetic levitation system. In the conventional MRAC scheme, the controller is designed to realize plant output converges to reference model output based on the plant which is linear. This scheme is effectively for controlling linear plants with unknown parameters. However, using MRAC to control the magnetic levitation system at real time is a difficult problem for Control system design because it has highly sensitivity for atmospheric disturbance. The proposed method presents design methodology of PID controller using MRAC technique and kalman filter for solving the problems. The adjustable PID parameters corresponding to changes in plant and disturbance will be determined by referring to the reference model specifying the properties of desired control system. Therefore, this technique is convenient to control the process for satisfying the requirement of the system performance

Keywords: Marc, Pid Controller , Magnetic Levitation, Kalman filter , Matlab, Adaptive control

1.INTRODUCTION

Model reference adaptive control (MRAC) has received considerable attention, and many new approaches has been applied to practical process. In the MRAC[1] scheme, the controller is designed to realize plant output converges to reference model output based on assumption that plant can be linearlized. Therefore, this scheme is effectively for controlling linear plants with unknown parameters. However, it may not assure for controlling nonlinear plants with unknown structures . The PID controllers[15] with fixed gain are unable to cope up with the problems discussed above. PID controllers have been recently developed to deal with such problems for electrical and mechanical systems. Also the concept of mit rule[13] has been applied . in order to enhance the dynamic characteristics of the PID controllers. Still, to obtain the complete adaptive nature, specific adaptive control techniques are needed. Adaptive control[5] changes the control algorithm coefficients in real time to compensate for variations in environment or in the system itself. It also varies. In order to use a Kalman filter[11].[12] to remove noise from a signal, the process that we are measuring must be able to be described by a linear system.Many physical processes,

2.MAGNETIC LEVITATION SYSTEMS

Magnetic levitation is the process of levitating an object by exploiting magnetic fields. In other words, it is overcoming the gravitational force on an object by applying a counteracting magnetic field. Either the magnetic force of repulsion or attraction can be used. In the case of magnetic attraction, the experiment is known as magnetic suspension. Using magnetic repulsion, it becomes magnetic levitation. In the past, magnetic levitation was attempted by using permanent magnets. Attempts were made to find the correct arrangement of permanent magnets to levitate another smaller magnet, or to suspend a magnet or some other object made of a ferrous material. It was however, mathematically proven by Earnshaw that a static arrangement of permanent magnets or charges could not stably magnetically levitate an object Apart from permanent magnets, other ways to produce magnetic fields can also be used to perform levitation. One of these is an electrodynamics system, which exploits Lenz's law. When a magnet is moving relative to a conductor in close proximity, a current is induced within the conductor. This induced current will cause an opposing magnetic field. This opposing magnetic field can be used to levitate a magnet. This means of overcoming the restrictions identified by Earnshaw is referred to as oscillation. Electrodynamics magnetic levitation also results from an effect observed in superconductors. This effect was observed by Meissner and is known as the Meissner effect. This is a special case of diamagnetism. This thesis will mainly deal with electromagnetic levitation using feedback techniques to attain stable levitation of a bar magnet

Figure **1:** diagram of magnetic levitation system

The force diagram of magnetic levitation system is shown in Fig.1. we can simply yield the equation of motion for the levitation system according to force balance analysis in vertical plane as

$$m\ddot{y} = f_u - mg - c\dot{y} \qquad (1)$$

where *m* is the mass of the levitation magnet, *y* are the distance of levitated magnet, and *Fu* is the magnetic force term that are modelled as having the following form

$$f_u = u/(a + b)^4 \qquad (2)$$

Where *a*, *b* and *c* are constants which may be determined by numerical modelling of the magnetic configuration or by empirical methods [7]. In this research we will try to control the height of the levitated magnet *y* by using input voltage *u* in the lower coil of the magnet levitation system [11]

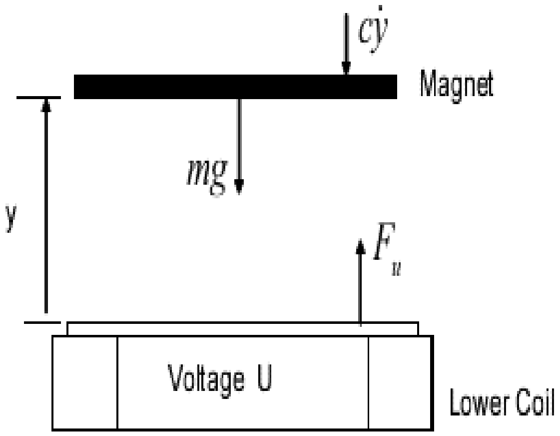

Figure **2:** Force diagram of magnetic levitation system

3.PID CONTROL

The PID algorithm remains the most popular approach for industrial process control, despite continual advances in control theory. This is not only because the PID algorithm has a simple structure which is conceptually easy to understand and implement in practice but also because the algorithm provides adequate performance in the vast majority of applications. A PID controller [4] may be considered as an extreme form of a phase lead-lag compensator with one pole at the origin and the other at infinity. Similarly, its cousin, the PI and the PD controllers, can also be regarded as extreme forms of phase-lag and phase-lead compensators, respectively. A standard PID controller is also known as the controller, whose transfer function is generally written in the

$$u(t) = k_p e(t) + k_i \int_0^t e(t)\, d\tau - k_d\, dy\,(t) \,/\, dt \qquad (3)$$

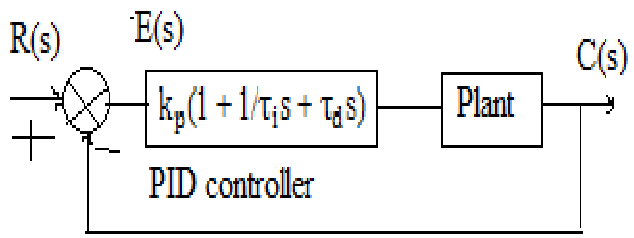

Figure **3:** PID control of a plant

4. MRAC

The model reference adaptive control (MRAC) was originally prposed to solve a problem in which the specifications are given in terms of a reference model that tells how the process output should responds to the command signal. The MRAC which was proposed by Whitaker in 1958 is an important adaptive controller A block diagram of MRAC [3] is illustrated in Fig. 2 The controller presented above can be thought of as consisting of two loops. The ordinary feedback loop which is called the inner loop composed of the process and controller. The parameters of the controller are adjusted by the adaptation loop on the basis of feedback from the difference between the process output y and the model output ym . The adaptation loop which is also called the outer loop adjusted the parameter in such a way that makes the difference small An important problem associated with the MRAC system is to determine the adjustment mechanism so that a stable system that brings the error to zero is obtained. The following parameter adjustment mechanism, called the MIT rule, was originally used in MRAC

$$d\theta / dt = -\gamma e\left(\frac{\partial e}{\partial \theta}\right) \quad (4)$$

Denotes the model error and θ is the controller parameter vector. The components of $\frac{\partial \theta}{\partial t}$ are the sensitivity derivatives of the error with respect to θ The

$$e(e = y - y_m) \quad (5)$$

parameter γ is known

This technique of adaptive control comes under the category of Non-dual adaptive control. A reference model describes system performance. The adaptive controller is then designed to force the system or plant to behave like the reference model. Model output is compared to the actual output, and the difference is used to adjust feedback controller parameters. MRAS[2] has two loops: an inner loop or regulator loop that is an ordinary control loop consisting of the plant and regulator, and an outer or adaptation loop that adjusts the parameters of the regulator in such a way as to drive the error between the model output and plant output to zero. Adaptation Mechanism: It is used to adjust the parameters in the control law. Adaptation law searches for the parameters such that the response of the plant which should be same as the reference model. It is designed to guarantee the stability of the control system as well as conversance of tracking error to zero. Mathematical techniques like MIT rule, Lyapunov theory[14] and theory of augmented error can be used to develop the adaptation mechanism. In this paper both MIT rule[13] and Lyapunov rule are used for this purpose.

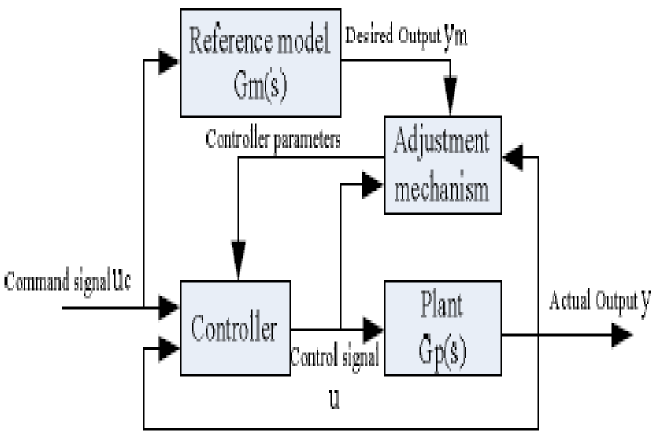

Figure **4:** main structure of mrac

5 .KALMAN FILTER

The Kalman filter estimates a process by using a form of feedback control. The filter estimates the process state at some time and then obtains feedback in the form of measurements. The equations for the Kalman filter can be divided into two groups: time update equations and measurement update equations. The time update equations are responsible for the feedback - i.e. for incorporating a new measurement into the a priori estimate to obtain an improved a posteriori estimate. The time update equations can also be thought of as predictor equations [11], while the measurement update equations can be thought of as corrector equations. Indeed the final estimation algorithm resembles that of a predictor-corrector algorithm for solving numerical problems as shown below in Fig. 5. [10]

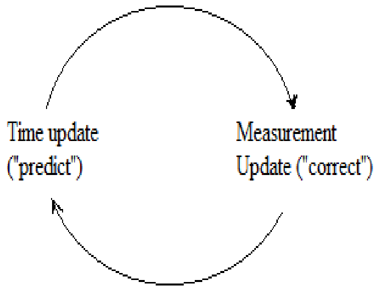

Figure **5:** The ongoing discrete Kalman filter cycle

The specific equations for the time and measurement updates are presented in Eq. (4) and Eq. (5)

$x^{\hat{}-}(k+1) = A(k)x^{\hat{}}(k) + (k)u(k)$ (4)

$p^{-}(k+1) = A(K)P(k)A^{T}(k) + Q(k)$ (5)

The time update equations in (4), (5) project the state and covariance estimates forward from time step n -1 to step n. The discrete Kalman filter measurement updates equations. The first task during the measurement update is to compute the Kalman gain, K_n .The next step is to actually measure the process to obtain the input Z_n, and then to generate a posteriori state estimate by incorporating the measurement as in Eq. (7). The final step is to obtain a posteriori error covariance estimate via Eq. (8).

$K(k) = p^{-}(k)H^{T}(k)(H(k)P^{-}(k)H^{T}(k) + R(K))^{-1}$ (6)

$x^{\hat{}}(k) + k(k)(z(k)-H(k)x^{\hat{}-}(k))$ (7)

$P(k) =(1-k(k)H(k)p^{-}(k)$ (8)

After each time and measurement update pair, the process is repeated with the previous a posteriori estimates used to project or predict the new a priori estimates[8].

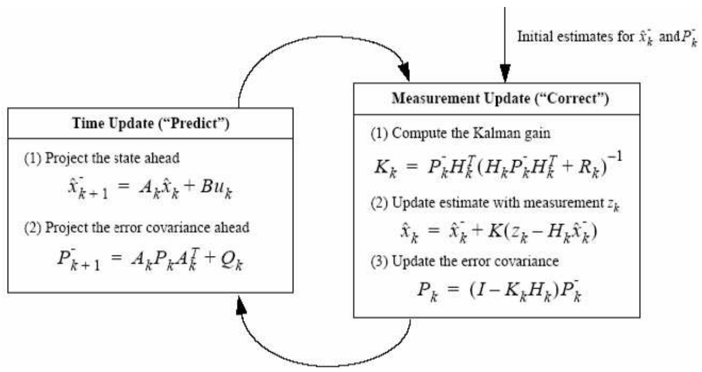

Figure **6:** Complete operations of Kalman Filter Algorithms

This recursive nature is one of the very appealing features of the Kalman filter. The Kalman filter instead recursively conditions the current estimate on all of the past measurements. Fig. 6.offers a complete picture of the operation of the filter, combining the high-level diagram of Fig. 6 with the Eq. (4) – Eq. (8).

6. SIMULATION

a simulation has been carried out with the following parameter values

1. plant model = 1/s+2
2. Reference model =100s +10000/s^2+140s+10000 frequency 0.1 Hz, and the simulating time is 100(s). Fig. 7and Fig.8 shows the reference model and process output

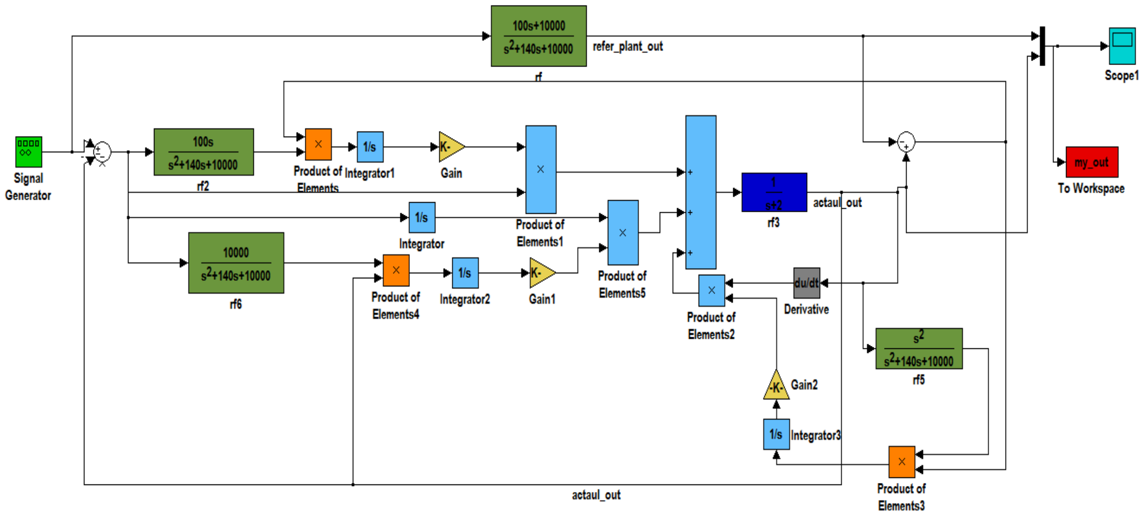

Figure 7: MRAC Simulation Block Diagram for the magnetic levitation System

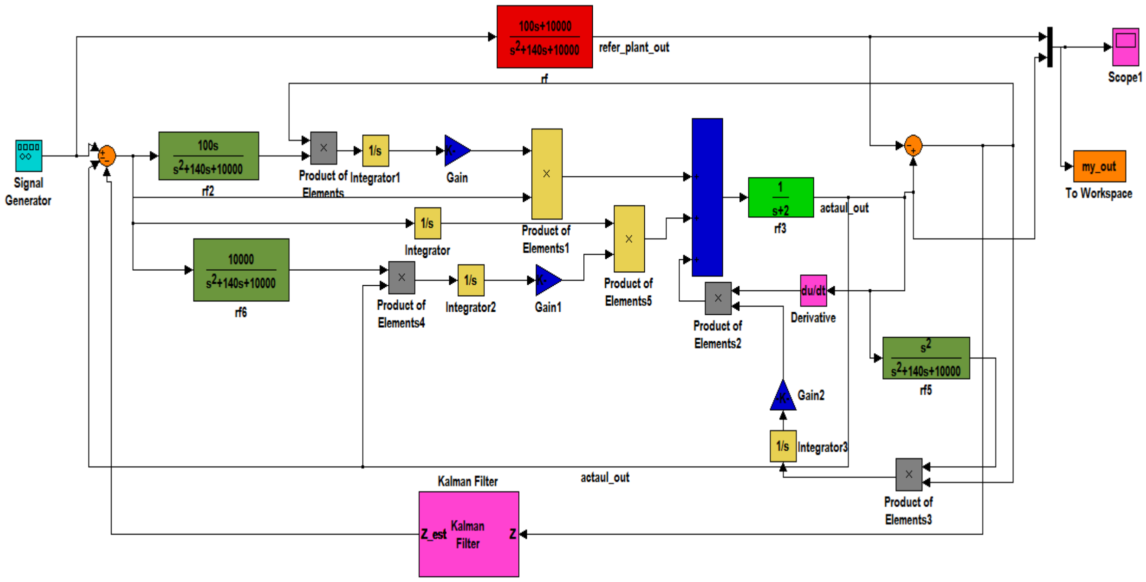

Figure 8: MRAC Simulation Block Diagram for the magnetic levitation System using Kalman filter

7. CONCLUSION

The results reveal us that the proposed method is an effective scheme to control the output of response of the Magnetic Levitation System. The Design of Magnetic Levitation system with the use Kalman Filter using MRAC Techniques process can conveniently adjust controller parameters corresponding to changes of plant and disturbance. It can control the output response satisfying the Specification of control system requirement with the use of Kalman Filter in MRAC to Control Magnetic Levitation System

8. ACKNOWLEDGMENT

I would like to thank Dr,(Mrs) Shileja Shukla for technical support and helpful discussions about Matlabs software programming

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Table 1.With out Kalman filter

model	Gain (γ)	Rise time (s) (t_r)	Overshoot(%) (m_p)	Setting time(s) (t_s)
Reference (ym)	-100	2.2	.998	3.2
Plant (y)	-100	2.00	.998	3.0

Table 2.With Kalman filter

model	Gain (γ)	Rise time (s) (t_r	Overshoot(%) (m_p)	Setting time(s) (t_s)
Reference (ym)	-1000	2.2	.998	3.2
Plant (y)	-1000	2.2	.998	3.2

10. RESULTS

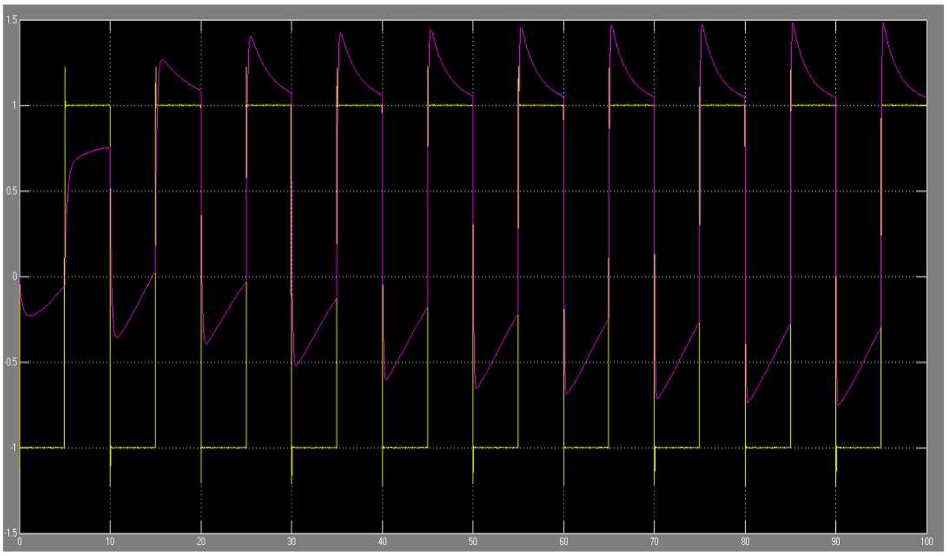

Figure 9: Outputs of reference model and plant whit out using Kalman filter in MRAC

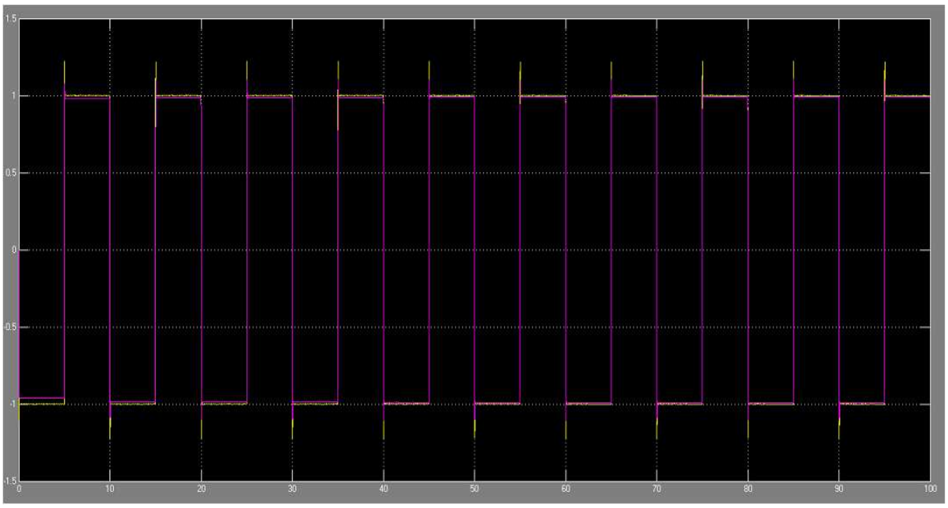

Figure 10: Outputs of reference model and plant when using with kalman filter in