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A Concise Survey of Self-tuning Methodologies for Proportional Integral Derivative Control system

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***Abstract*— The primary aim of this research paper is to provide a comprehensive reference source for researchers working with self-tuning Proportional Integral Derivative (PID) control systems and also, offers the study on such self-tuning methodology. The need for our survey arises because the auto-tuning of PID control system may give a good set-point tracking and interruption rejection, which is used under traditional as well as advanced PID control systems for different control applications from long time. Correctly chosen self-tuning method may provide a proficient performance, stability and robustness in the PID controlled system. The survey has been carried into categories based on classical techniques developed for the PID self-tuning and optimization techniques applied for self-tuning mechanism for the better transient and steady state characteristics. Also, an assessment among different self-tuning techniques for PID Control system have been studied and analyzed under this survey.**

Keywords*— *PID control system, Self-tuning, Optimization, Set-point tracking and Disturbance rejection.

I. INTRODUCTION

Proportional Integral Derivative (PID) control system provides ease in intentions of the major proficient response to approximately every genuine control application. Because of it, PID is widely applied in control engineering applications. Transient as well as steady-state result of system provides entire details of given system. The tuning of PID control system is having the ability to fill the error gaps in both, transient as well as steady-state result. To heighten the response of the controllability of classical PID tuning techniques, various ideas have been proposed. Numerous techniques were accepted in existing work to find PID parameters in control systems [1].

Many times, the traditional techniques of tuning for PID control system design fails to accomplish acceptable performance with higher order control design, having more time delay, not-linear as well as many more. Working with recent PID technology together with PID firmware scripts, marketable PID hardware units as well as original PID tuning policy is provided in [2].

A full-pledged technique for developing a PID control system having a different performance index is obtained in [26]. This is based on novel technique stimulated by adaptive social behavior of humanity, named as Adaptive Social Behavior Optimization [3].

The quad-rotor control system design estimation of distribution algorithms (EDAs) have applied in [4]. This is supported by significant distribution of improved result through the search procedure.

Self organize genetic algorithm (SOGA) is modified version of genetic algorithm (GA) proposed in [5]. Method is based on increasing the capability of genetic algorithm to attain the global outcome along a variant mutation operator. This is applied to provide a self-tuning to the control system of two different plants.

A relative researches have been done in [6] between GA and "Differential Evolution (DE)" of various industry along with many indices for modifying the analogous control system. The PID tuning through concave convex optimization technical has provided in [7].

A fusion of bacterial foraging algorithm, genetic algorithm has presented and relative benefits of these strategies over individual algorithm for numeric optimization has presented in [8]. Both methods are applied for the tuning the control system of AVR.

Chaotic optimization has been used on Lozi Map in [9]. This technique is for modifying the AVR design for many setting requirements. The theory of improved investigation of the global result by applying the chaotic sequence in two different phases has practiced.

Auto-tuning functions of PID control systems require division of the tuning cycles (normally cyclic and so time taking) from the control iterations. Most of real-time system uses, this advanced technique can be reason of serious deadline linked issues and finally can cause system breakdown.

Section II has a Literature Review covers self-tuning and optimization methods. Under Section III perceptive of PID control system is presented with various tuning parameters along with self-tuning methodologies. Conclusion of various self-tuning methods comes under section IV.

II. LITERATURE REVIEW

In time delay systems the Robust PID Control systems synthesized and researcher designs a PID tuning technique built on variable space tactic. Till now, the synthesis stage can be applicable to period interruption systems, but essential outcomes in the real world use are currently unavailable. Moreover, the evaluation stage is not established in the existing work and outcome has not been evaluated and compared to present tuning approaches. To rectify the issues, parameter space approach was used in double stage. Under *control system synthesis* stage, the constant (i.e. Hurwitz) area in the domain of control system parameters k for various representatives out of Q (typically vertices) may be figured out. A parameter with respect to robust control system k is selected through stable region junction. Feedback *analysis* is practiced to validate strong stability throughout range of entire Q values. After this we figure out the stable region in the domain of system variables with set control system. While Q lies completely in stable space, then a clarification of original issue can be computed [10].

The rigid stable space of PID variables for ambiguous control systems along time delay by means of D-partition method is presented for overall gains for each PID control systems. This assures an excellent performance check to an available transfer function. This could be of any order with time delay by means of the output in frequency domain [11].

In [12], each digital PID control systems through Field Programmable Gate array (FPGA) has been implemented. Currently embedded control use needs low power with speedy PID control systems along with feedback response through limited resources, causing budget saving. Digital PID control system error output is produced through analogous comparator.

In [13], author defines the outcomes of the current data mining. This is linked with large scale live data fission. Also, the scattered and diverse arrays of sensors, dispersed control as well as the interaction for peer-to-peer system to administer system node drop outs, the spatially dispersed arrangements of may antenna of RF networked sensors, and network reconfiguration tactics among others as well as how to balance the outcomes.

The various kinds of delays in networked control systems based on discrete time system tactics, fuzzy logic technique, and feedback control technique on a data network on various uses and Networked Control System (NCS) arrangements provides an improved technique on existing networked traffic method based on gain scheduling approach over IP networks [14].

In article [15], a fractional adaptation technique to refrain the control system variable in fuzzy systems were specified, as well as mathematical model of a circuit dependent direct current motor was adopted for demonstrating usefulness through suggested method at place of direct Proportional-Integral control system variable correction. Also the complete adjustable fuzzy system, technique adopted, in that the resultant parameters as well as associated operations parameters are adjusted to enhance system outcome.

An auto tuned Fuzzy Control system of type 1st and 2nd level considered by various authors to control a Networked Control System in presence of delay as well as deformability in packets.

In [16], a Networked Control System covering a clock based sensors and event-based control system with actuators are analyzed with respect to time. A correlation among sampling rate and delay triggered by network were evaluated. This was performed in stability graph and through hybrid models method and evaluated stability in Networked Control System.

The Networked Control System for motor rotation rate management can be done by means of a Profibus DP Network to outcome estimation as well as author projected a customized and conventional design method for PID control system that reduces the effects of network interruptions on the actual scheme. The two approaches are compared by means of settling time and peak overshoots of Cohen Coon method & Ziegler – Nichols method and then they were applied for implementing the PID control systems. Work studies the performance of IMC tuning for PID control system with other tuning algorithms for PID control system like Cohen–Coon, Chein, Hrones and Reswiclc (CHR). The algorithms are investigated for performance measures such as time response features, integral error criteria and robustness [17].
Computational techniques for computing the group of entire stabilizing control systems, of a known order and configuration, for linear time invariant (LTI) delay-less models were presented in [18]. Through this work, aim is to find the stabilizing area in the parameter domain of simple control systems because stabilization is a basic stage in every design. When control system group of a required order and structure is found, next design criterion may be included. To this end, various methodologies are incorporated, among which extensions of the Hermite- Biehler [19].

III. TUNING PID PARAMETERS AND SELF-TUNING METHODOLOGIES

In PID control system there are many techniques that are used for self-tuning of the Proportional-Integral-Derivative parameters as well as its optimization. Self-tuning PID parameters and various optimization methods are summarized as follows.

A. Tuning PID Parameters

Various research papers defines various terms that are used to stabilize or set the system to near stabilized condition, these terms are the tuning parameters. The basic parameter that defines the characteristics of PID control system may be written as:

$$G(s) = K_P + K_I \frac{1}{s} + K_D s$$

Where, K_P, K_I, *and* K_D are defined as gain constants for proportional, integral and derivative functions respectively. Design behavior of these parameters is characterized as:

- The proportional constant factor (K_P): This provides entire control achievement relative to the error signal by the way of whole-pass gain term.
- The integral constant factor (K_I): This provides decreasing steady-state errors by low-frequency counterpart.
- The derivative constant factor (K_D): Enhancing transient output via high-frequency counterpart.

Assuming z as the incessantly differentiable matrix non-imaginary operation characterized for $z \epsilon s$, where $\{z \epsilon \mathcal{R}^3 | 0 \leqslant z_i \leqslant \infty, \text{for } i=1,2,3\}$. Self-tuning is described to be optimization challenge to calculate $z^* = [K_P^*, K_I^*, K_D^*]$ so that a characterized performance index of the plant may be reduced. Some researchers like Hohenbitchler and Ziegler-Nichols uses gain and phase margins to find the stability regions.

B. Self-tuning Methodologies

The configuration of digital PID control system was described in [27]. The policy-based computing might be applicable in providing the control system with ability in regulating its performance according to the environmental variations. This scheme provides easier reconfiguration structural, in the way of activating particular components along with syntactical, as well as limit verification and service operations. It is required to design auto-tuning, reconfigurable along with framework responsiveness signs into digital PID control system. This methodology carries needed characteristics of tuning. Furthermore, this is independent of Fuzzy Logic and Evolutionary Algorithms.

The typical self-tuning logic and the ideal of tuning algorithm are estimated to get into the process not only the variables those are firmly associated with controller design , and few conditions, they got straight effect over control method like process noise and disorders. In addition to this, as the alternative of self-tuning technique typically triggers attainable kind of most favorable solution, it would be extremely preferred that the main mechanism of the tuning technique. The tuning ideas were replaceable such a way the tuning itself was flexible and can fulfill various contradicting tuning requirements.

Tuning rules are initially based on control system parameters and primarily suggested, they uses the tangent technique to determine the parameters. Another tuning rule can be named as “Ultimate Cycling Tuning Rule” that can be formed by gains of control system and period of oscillation period at ultimate frequency; such model is firstly proposed in [1]. The other model depends on gain and phase margin in IPD form was given in [20].

Tuning procedures that are based on direct synthesis uses frequency domain techniques. In [21-22] authors describe such system for stable and unstable control systems.
In fine tuning, proportional, integral and derivative gains are fine-tuned until acceptable output obtained. Some other methods that are studied by the researchers are “chin, hornes and reswick method”, “lambda tuning technique”, “direct tuning methods”.

Iterative methods can be used as manual tuning which is actual appropriate method where compensator variables can get through experimentation, that’s why it is called manual tuning. These methods are creates delay and there is a limitation on stability.

For time/frequency domains there are otherwise, graphical and analytical techniques are available for tuning of control system. The time domain design can be accomplished by root locus diagrams, but in this method the delayed processes cannot be modeled. The frequency based approaches are utilizing Bode plots technique to find a desired phase margin. First approximation can be found by the iterative methods which are the desirable control system parameters.

All approaches that are proposed by investigators follow the two criteria to improve the result and they are Gain Margin (GM) and Phase Margin (PM). GM is the quantity of gain increases/decreases essential to bring loop gain at 1.0 for given frequency. While, phase margin is a variation among phase outcome as well as -180° during unity feedback gain.

To track set-point, various set point Iterative data control hybridized with PID. This is to improve the transient response and dynamic act. Also, it is to the fine-tuning of input to the plant during upcoming system process based on the errors observed [23].
In many thermal power generation processes, systems typically show 1st Order along with Dead Time features. More consumption of time makes self-tuning control as a critical part. Under this condition, the controlled plant would be made to produce a undesired response. It will disturb protection as well as process constancy.

An enhanced system optimizes the desired range of the aimed PM by frequency response. After it, achieves a result to compute the aimed PM. The constraints in critical response are applied to recognize system for acquiring impulse response of control item.

Effective technique is used to work out the adjustment coefficient of the phase angle margin auto-tuning method. Along with it, satisfactory control system parameters are obtained. The upgraded PM online auto-tuning algorithm can enhance the Industrial control feature. Design modification can be quicker along with minimized overshoot. The oscillation strength of parameter is harmless as well as consistent throughout settling procedure and process outcome is acceptable. A better-quality tuning procedure associated with phase margin achieves risk free and practicable solution in use of speedy online auto-tuning technique in various electric process industries [24].

Some fuzzy logic control systems possibly considered as nonlinear PID control systems. The fuzzy logic works well under the varying system parameters but to make the control system much precise the static initial gain must be chosen properly to avoid the sub-optimal result. To execute this, another fuzzy logic is used to wisely tune the static initial gains working in parallel along with the fuzzy tuned PID control process. This added fuzzy logic control method offers the compensation in the gain tuning with ability to respond under fluctuating system parameters and making the system much consistent in the close loop operation.
Adaptive fuzzy logic practice is designed to regulator the design. Fuzzy logic works as gain tuner for PID control system by computing the K_P, K_I, K_D gains.

It can be witnessed from the speed and torque profile and the output mechanical power that the control system have a better response and works fine under moving load parameters. The proposed control system in [25] causes the system to work powerfully and less amount of output mechanical power is expended in modeling of electric controlled vehicle allowing for the vehicle design, constrain train, revolving wheel and load dynamics. This control design works well to eliminate the transient oscillations and guarantee better system response under all the conditions and attained the better performance of electric vehicle along with an optimal balance of acceleration, velocity, travelling range, improved control system quality and response.
Tuned the PID controller for AVR system using different methods like ZN-Tyerus Luyben, ZNAstrom Hugglund, Singular frequency and Internal Model Control. It has been observed that Internal Model Control type of controller gives least maximum overshoot but takes tile more time to settle [28].

Table 3.1. Comparison of Self-tuning Methods

S.No	Tuning Method	Advantages	Limitations
1.	Policy-based computing.	Flexible and Offers simple reconfiguration structure.	Entire system stability is difficult.
2.	Improved Phase Margin auto-tuning method	The design adjustment is speedy and overshoot is less.	Settling time can be improved.
3.	Fuzzy logic based gain tuning method.	Removes transient oscillations and gives fast and accurate torque response under all conditions.	To works well under the varying system parameters, precise the static initial gain must be selected properly. This is required to avoid the sub-optimal response.
4.	ILC based Gain scheduling PID	Efficient control strategy for controlling a highly non-linear dynamic system.	Overshoot is observed in the response.
5.	Internal Model Control type	Least maximum overshoot	Transient time is more
6.	ZN-Tyerus Luyben tuneing.	Minimum transient time.	Disturbance exists still settling period.
7.	Convex-concave Optimization	Guaranteed Convergence.	Problem with initial controller Stability in case of open loop unsterilized plants.
8.	Hybridized Genetic and Bacterial Foraging algorithm	Global Optimization on noisy regions.	Depends only on theoretical laws.
9.	Chaotic Optimization on Automatic Voltage Regulator	Good in global and local search.	Step size needs to be self-adjusted for more effectiveness of the system response.
10.	D-partition Technique	Simple and effective for any order time delay system.	Parameter selection must be from stable region.

The above table consolidates the different tuning methods along with their advantages and limitations.

IV. CONCLUSIONS

This paper presents a brief review of recent researches and their techniques for optimizing the response of PID control system along with details of the work done in tuning and self tuning. The diversity of researches done by various researchers have summarized and studied in this paper. A comprehensive relative study of every technique still needs to be tested at once, under diverse conditions to estimate the comparative performance of different techniques on a widespread platform. In the future performance of self-tuning can be improved by applying more rigorous techniques and evaluated with the new performance index; an improvement would reduce the maximum overshoot, settling time of transient and for better steady state characteristics.

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