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RESEARCH ARTICLE

GA/PSO BASED PID CONTROLLER FOR PROCESS CONTROL SYSTEM

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ABSTRACT

The main objective in this study is to control the process variables (water level, temperature and flow control) of PCT 100 machine using PID controller which will be tuned by PSO/GA algorithms. The proposed work is to do automatic tuning of PID controller parameters i.e. K_P, K_I, K_D, by intelligent methods such as GA/PSO. So the problem of tuning the PID parameters manually is eliminated and automatic tuning gives better results.

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INTRODUCTION

Process as used in the terms process control and process industry, refers to the methods of changing or refining raw materials to create end products. The raw materials, which either pass through or remain in a liquid, gaseous, or slurry (a mix of solids and liquids) state during the process, are transferred, measured, mixed, heated or cooled, filtered, stored, or handled in some other way to produce the end product. Process control refers to the methods that are used to control process variables when manufacturing a product. For example, factors such as the proportion of one ingredient to another, the temperature of the materials, how well the ingredients are mixed, and the pressure under which the materials are held can significantly impact the quality of an end product. Manufacturers control the production process for three reasons:

- Reduce variability
- Increase efficiency
- Ensure safety

The basis for analysis of a system is the foundation provided by linear system theory, which assumes a cause effect relationship for the component of a system. Therefore a component or process to be controlled can be represented by a block as shown in Fig.1.

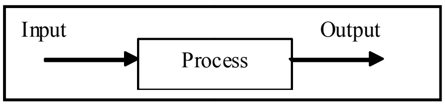

Fig. 1.

The three main categories by which a process can be controlled are: ON/OFF control, open loop control and closed loop control.

A proportional-integral-derivative (PID) controller is a generic control loop feedback mechanism widely used in industrial control systems. A PID controller calculates an "error" value as the difference between a measured process variable and a desired set point. The controller attempts to minimize the error by adjusting the process control inputs. The PID controller calculation involves three separate parameters and is accordingly some time called three-term control: the proportional, the integral and derivative values, denoted P, I, and D. The weighted sum of these three actions is used to adjust the process via a control element called actuator. This paper is focused on to improve the performance of PID controller of the bench-top system which implements several continuous fluid processes. This system is normally found in

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food and drinks manufacturing, petrochemicals production, water purification, sewage processing and many other area of industry. The paper is organized as follows: in Sec. II is briefly described, for the reader's convenience, the salient features of Processes Rig PCT-100considered throughout the paper. Sec. III contains the details of the software designing to improve the performance of PID controller and the block diagram of the designed software is described, together with the experiment conceived for estimating the performance of PID controller. The simulink models used is described in Sec. IV. Some experimental results are then reported in Sec. V, and conclusions in Sec. VI.

PROCESS RIG PCT-100

The PCT-100, Process Control Technology unit, is a fully integrated, self-contained bench top apparatus consisting of a Process Module, and a Control Console with a built in power supply. A Windows based software with full control and data acquisition is included. A number of experiments in process control are included covering flow, level, pressure, temperature, and combinations of the processes. The Control Console is easily connected to a PC using the USB connection or to a PLC using a D type connector. The Console has a mimic of the Process Module on the front and includes fault switches, and test points from all of the transducers. Level is measured using a 0 to10V magnetostrictive sensor; pressure is measured using a gauge 0 to 5bar sensor and flow using a turbine flow rate sensor. PT100 is used to measure temperature in both the sump and process tank. The front of the control module has a schematic of the Process Rig, ON/OFF indicator, six illuminated fault switches, test points, indicators to show the operational status of the elements on the rig, and a backlight switch to turn on the backlights for the displays on the rig shown in Fig 2.

Fig. 2. Process Rig PCT-100 Kit

A diverter valve is used to direct the liquid through a forced air cooling process to cool the liquid in the system. Two proportional valves are used to control flow in to and out of the process tank, a manually adjustable needle valve is used to add disturbances to the system and a pressure relief valve fitted for safety. Data is displayed on the five LCD displays fitted to the Process Module, and through the software data can be monitored, saved or printed. The software has a PID controller with Supervisory Control and Data Acquisition and trending features.

The PC based control system consist of the following elements. Fig. 3 shows the block diagram of PCT-100 digital control loops.

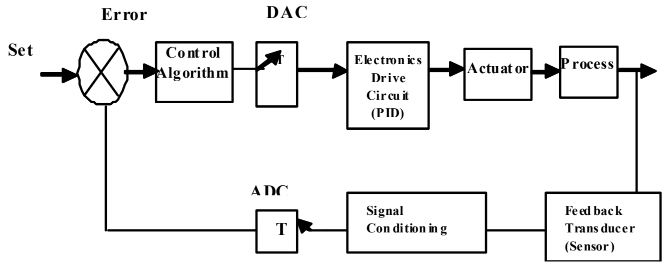


Fig. 3. Block Diagram of PCT-100 Digital Control Loops

- Control Algorithm – GA/PSO is used to search optimization of PID controller i.e. K_P, K_I, K_D.
- PID Controller- A PID controller calculates an error value as the difference between a measured process variable and a desired setpoint. The controller attempts to minimize the error by adjusting the process through use of a manipulated variable.
- DAC- In all digital control loops the controller output is converted to an analogue signal with a DAC, usually followed by a zero order hold device.
- Actuator – Actuators are used to change the valve settings.
- Process- Process includes level, flow, temperature, pressure control in Process Rig.
- Feedback Transducer – The process variable is measured using feedback transducer and this signal is sampled every T seconds by the control module.
- Signal Conditioning- Signal conditioning used to convert the current signal into voltage with amplified value to interface it with ADC.

Software implementation

PSO/GA algorithms are implemented using MATLAB Software, in order to control the process variables of PCT 100 machine. As the first step, mathematical modeling of the PCT 100 machine for its each process variables is done. After that the SIMULINK Model is formed from these equations either by taking the Laplace Transformation of these mathematical equations or by directly representing the equations in Simulink Model. Input and output are shown. Then the PID controller is used to control the process variable. The tuning of PID controller's parameters K_p, K_i, and K_d (proportional, integral and derivative constants) is done by PSO/GA algorithms. PSO/GA algorithms tune the PID parameter in such a way so as to minimize our fitness or objective function and to achieve the desired set point. The block diagram to tune the control process variable using PSO/GA algorithms is shown in Fig 4, the desired input is fed to the comparator which compares the desired input and controlled output. The resulting error signal is then fed to the PID controller. Then depending on the error signal, PID controller controls the process and then this output is again fed to comparator and this whole process continuously run till the error becomes zero i.e. till we get our set point. When we tune the parameters of PID controller by PSO/GA algorithm, then the whole process will run till the numbers of iterations are finished.

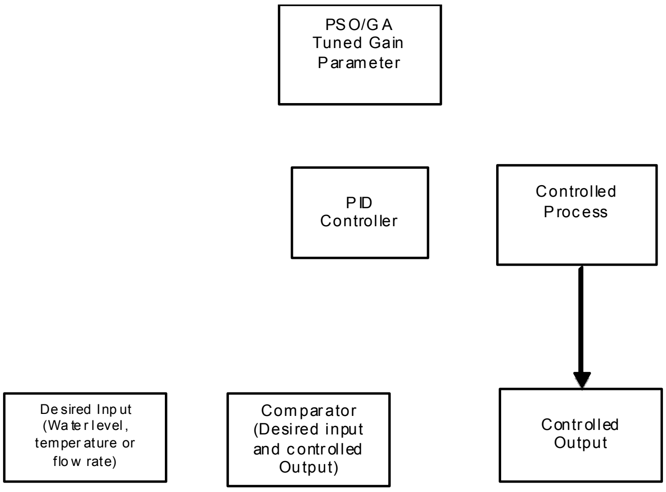


Fig. 4. Block Diagram to Tune the Control Process Variable Using PSO/GA Algorithms

Simulink model for different process variables

The mathematical modeling of Process Rig PCT 100 for each of its process variables has been done. The PID controller is used to control the process variables such as water level, temperature and flow rate. The simulation of Process Rig PCT 100 for each process variables has been done in MATLAB. The SIMULINK model of each process variables has been controlled by PID controller. The tuning of PID controller parameters has been done by using GA/PSO algorithm. Fig.5 shows the SIMULINK Model to Control Water Level of PCT-100 Using PSO/GA Algorith, Fig. 6 shows SIMULINK Model to Control Temperature of PCT-100 using PSO/GA Algorithm and Fig. 7 shows the SIMULINK Model to Control Flow Rate of PCT-100 using PSO/GA Algorithm.

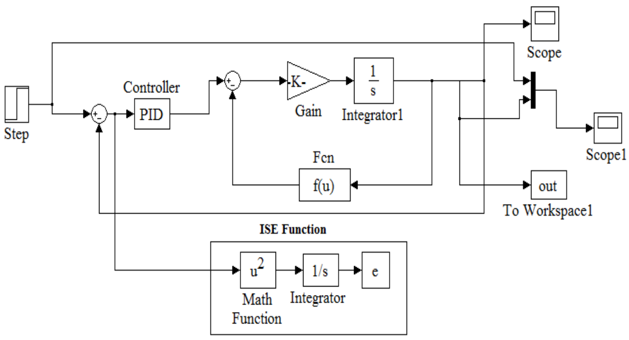


Fig. 5. SIMULINK Model to Control Water Level of PCT-100 Using PSO/GA Algorithm

The SIMULINK modelsin Fig.5, Fig.6 and Fig.7have been incorporated with PID controller. The desired set point is defined by unit step function. The m files containing the PSO and GA codes are simultaneously run along with the SIMULINK model to obtain the tuned parameters of the PID controller. Two scopes are used. First scope is used to calculate the value of Rise Time, Settling Time, Overshoot and Steady State Error. Scope1 gives the waveform of Set point and measured variables are obtained simultaneously.

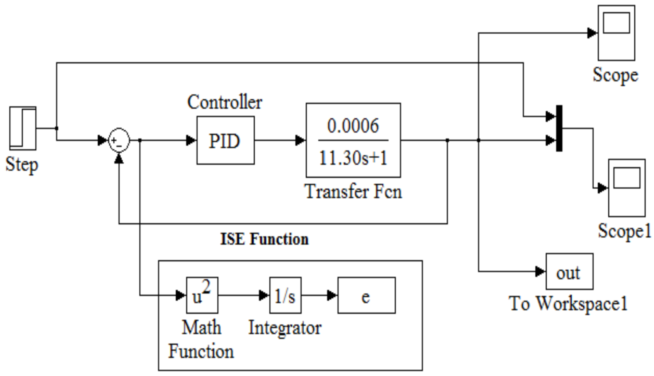


Fig. 6. SIMULINK Model to Control Temperature of PCT-100 Using PSO/GA Algorithm

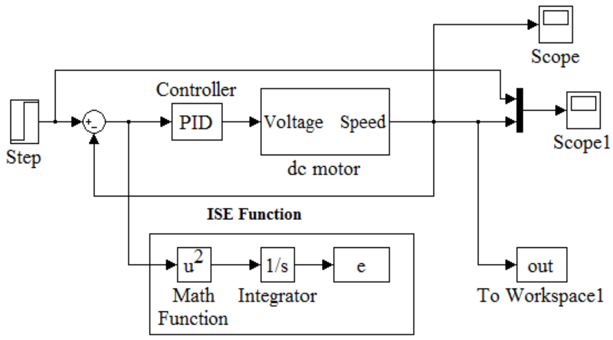


Fig. 7. SIMULINK Model to Control Flow Rateof PCT-100 Using PSO/GA Algorithm

RESULTS AND DISCUSSION

After implementing the PSO and GA algorithm to control the PID parameter, the results are obtained. The rise time, settling time, steady state error and overshoot is compared with and without PSO and GA algorithms.

Table 1. Water level Control at Different Setpoints

Control method for PID controller	Setpoint (^{0}C)	System Performance Parameters			
		Settling Time (s)	Rise Time (s)	Steady State error (%)	Overshoot (%)
Temperature control On PCT 100	35	60.203	40.203	9.45	0
	45	59.407	59.203	13.27	0
	55	59.603	59.406	20.1	0
	70	59.406	59.203	31.96	0
	80	59.406	59.203	30.01	0
	90	59.406	59.203	48.04	0

A. Experimental Results of Process Rig PCT 100 Process Variables

The results of the process variables such as water level control, temperature control, and flow rate control are done with the help of Process Rig PCT 100.The results of the process variables such as water level control, temperature control, and flow rate control are done with the help of Processes Rig PCT 100. The flow rate control of water at set point 1 L/m is carried out. At that time temperature of sump tank is 29.4 ^{0}C and the temperature of process tank is 24.5 ^{0}C, level percentage is 54.2 and flow rate is 1.03 L/m. Tables 1, 2 and 3 shows the experimental results for water level, temperature and flow rate control at different set points.

Table 2. Temperature Control at Different Setpoints

Control method for PID controller	Setpoint (cm)	System Performance Parameters			
		Settling Time(s)	Rise time(s)	Steady State error (%)	Overshoot (%)
Water level control On PCT 100	30	47.807	13.04	0.59	0
	45	35.010	5.604	0.10	0
	60	23.604	8.807	0.39	0
	70	30.416	10.506	0.20	0
	80	40.010	9.504	0	0
	90	58.60	10.39	0.20	0

Table 3. Flow Rate Control at Different Setpoints

Control method for PID controller	Setpoint (Litre/min)	System Performance Parameters			
		Settling Time (s)	Rise Time (s)	Steady State error (%)	Overshoot (%)
Flow Rate control On PCT 100	0.5	26.609	1.110	0.73	1.52
	1.5	20.016	0.916	0.52	1.89
	2.5	18.015	0.694	0.10	2.75
	3.5	17.204	1.000	0.10	2.83

Table 4. Water level Control at Different Setpoints

Control method for PID controller	Setpoint (cm)	System Performance Parameters			
		Settling Time (s)	Rise Time (s)	Steady State error (%)	Overshoot (%)
Water level control without PSO/GA	30	37.150	8.430	0.548	0.013
	45	32.970	4.826	0.345	0.454
	60	38.950	5.832	0.406	0.301
	70	39.360	8.542	0.5374	0.4550
	80	37.146	11.250	1.051	0.4552
	90	40.147	12.503	2.054	0.4553

Table 5. Temperature Control at Different Setpoints

Control method for PID controller	Setpoint (^{0}C)	System Performance Parameters			
		Settling Time (s)	Rise Time (s)	Steady State error (%)	Overshoot (%)
Temperature control without PSO/GA	35	43.91	24.69	38.81	0
	45	43.91	24.69	44.75	0
	60	43.91	24.69	59.70	0
	70	43.91	24.69	69.62	0
	80	43.91	24.69	79.57	0
	90	43.91	24.69	89.51	0

Table 6. Flow Rate Control at Different Setpoints

Control method for PID controller	Setpoint (Litre/min)	System Performance Parameters			
		Settling Time(s)	Rise Time(s)	Steady State error (%)	Overshoot (%)
Flow Rate control without PSO/GA	0.5	30.403	0.842	0.017	0.008
	1.5	28.179	0.839	0.058	0.025
	2.5	25.317	0.830	0.087	0.087
	3.5	22.201	0.826	0.163	0.763

B.Simulation Results Of Process Variables Without Using Ga/Pso

The simulation results of different process variables water level control, temperature control, and flow rate control have been controlled by a PID controller. The simulation results obtained with respect to these different process variables at different set points are listed in Tables 4, 5 and 6.

C. Simulation Results Of Process Variables Using GA/PSO

To analyze the performance of Process Rig PCT 100 by implementing PSO/GA algorithms it has been modeled by means of SIMULINK as explained earlier. The different process variables such as water level, temperature and flow rate have been controlled by a PID controller whose parameters are tuned by GA/PSO algorithm. The simulation results are obtained with respect to these different process variables and are discussed in this section. Simulation is done for water level control with the setpoint at 30cm using genetic algorithm change is shown in Fig. 8. The rise time obtained from scope is 0.2635s, settling time is 0.4598s, steady state error is 0.149 and overshoot is 0.2292.

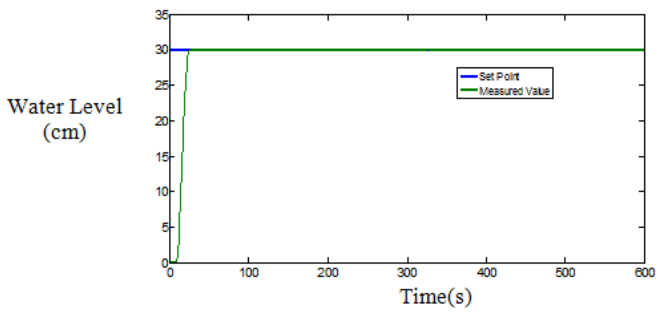
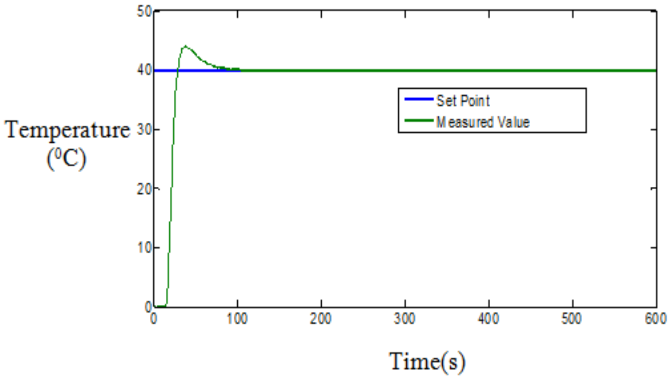


Fig. 8. Water Level Control Using GA Algorithm at SP = 30cm

Fig. 8 Water Level Control Using GA Algorithm at SP = 30cm The simulation result of temperature control at setpoint 40 ^{0}C using genetic algorithm shown in Fig. 9. It has been obtained from the scope the rise time is 0.7433s, settling time is 5.1857s, overshoot is 9.9319 and the steady state Error is 0. Simulation is done using genetic algorithm with a setpoint of 1L/m and the response as shown in Fig. 10. The value of rise time is 0.0677s, settling time is 0.7586s, steady state error is 0 and overshoot is 7.3802. Similarly the parameters of PID controller are tuned using PSO algorithm shown in Fig. 11 and different values are recorded.

D. Comparison of Experimental and Simulation Results with and without PSO/GA Algorithm at Various Setpoint

The comparison of experimental and simulation results of process variables such as water level, temperature and flow rate is done. The comparison of temperature control is shown in Tables 7. The experimentation is done with the help of Processes Rig PCT 100 and simulation is done using MATLAB. Similarly the comparison of water level and flow rate control is performed and the researcher analyzed that the overall performance of the system using GA and PSO algorithm is better than the system without using GA/PSO algorithm and Process Rig PCT 100.



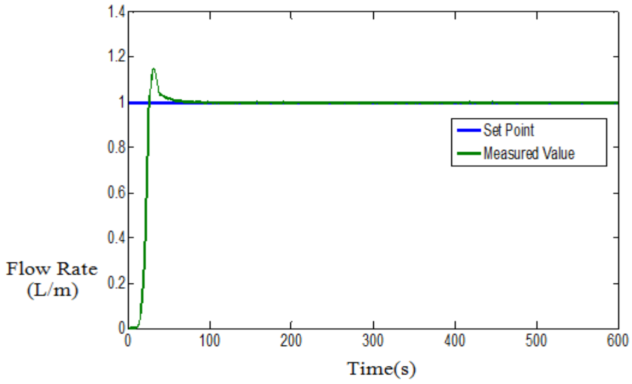


Fig. 9. Control of Temperature Using GA Algorithm at SP = 40 ^{0}C

Fig. 10. Control of Flow Rater Using GA Algorithm at SP = 1L/m

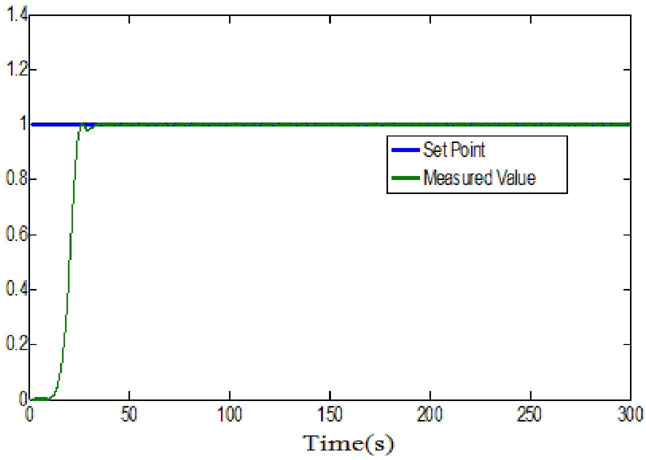


Fig. 11. Control of Flow Rate Using PSO Algorithm at SP = 1L/m

Table 7. Comparison of Experimental and Simulation Results Temprature Control using and not using GA/PSO

Set Point (^{0}C)	Control method for PID controller	System Performance Parameters			
		Settling Time (s)	Rise Time (s)	Steady State error (%)	Overshoot (%)
35	On Processes Rig	60.203	40.203	9.45	0
	Without PSO/GA	43.91	24.69	38.81	0
	With GA	5.1869	0.7438	0	0
	With PSO	1.2146	0.7480	0.05	1.4059
45	On Processes Rig	59.407	59.203	13.27	0
	Without PSO/GA	43.91	24.69	40.75	0
	With GA	5.1856	0.7430	0.01	9.9323
	With PSO	1.0584	0.6387	0.05	0.8793
55	On Processes Rig	59.603	59.406	20.1	0
	Without PSO/GA	43.91	24.69	42.70	0
	With GA	5.2054	0.7438	0.01	9.8609
	With PSO	1.2753	0.7519	0.15	0.5473
70	On Processes Rig	59.406	59.203	31.96	0
	Without PSO/GA	43.91	24.69	38.62	0
	With GA	5.1809	0.7413	0.15	9.9146
	With PSO	1.1249	0.6812	0.30	0.9144
80	On Processes Rig	59.406	59.203	30.01	0
	Without PSO/GA	43.91	24.69	35.57	0
	With GA	4.8365	0.8956	0.10	18.3232
	With PSO	1.1402	0.6948	0.40	0
90	On Processes Rig	59.406	59.203	48.04	0
	Without PSO/GA	43.91	24.69	47.51	0
	With GA	5.4278	0.7823	0.10	9.7866
	With PSO	1.2277	0.7648	0.50	1.3757

Conclusion

The main objective of this work is to improve the performance of PID controller for process variables. The PID controller is used to control the process variables. The parameters of PID controller has been tuned by using PSO/GA algorithm because manual tuning of the PID controller is a tedious process and it takes very long time because it is based on hit and trial method. So to make the PID controller speed faster, PSO/GA algorithm is used. PSO/GA algorithms tune the PID controller parameters by reducing the fitness function which is error function. In each iteration of PSO algorithm and in each generation of GA algorithm, the value of error function is reduced and gets the steady state value. The performance parameters (rise time, settling time, steady state error and overshoot) are improved by using PSO/GA algorithm. The codes for PSO algorithm and GA algorithm were written in Matlab. The SIMULINK models for different process variables was developed and simulated through MATLAB m files containing PSO/GA code.

Future scope

In PSO and GA algorithms, both have some drawback. In GA, in spite of its capability of searching solution in parallel, crossover and mutation rates can subtly affect the convergence and also its ability to control convergence is less than PSO. The drawback of PSO is that the swarm may prematurely converge. A further drawback is that stochastic approaches have problem–dependent performances. This dependency usually results from the parameter settings in each algorithm. The problem dependency can be addressed through hybrid mechanism. It combines different approaches, so that the advantages of each approach can be benefited.

Hybrid algorithm, comprising merits of both GA and PSO is used to get optimal gain parameters of PID controller to improve the performance of PID controller. Then PID gain parameters are obtained by tuning with GA, PSO and Hybrid algorithm using objective function as linear relation with system specification as rise time, settling time, peak over shoot and integral square error (ISE). System response owing to these parameters is compared. Hybrid algorithm is expected to overcome the weakness of GA, PSO tuning techniques and to be more acceptable for industrial practice.

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