Implementation of SMC Control Action with Pi Sliding Surface for Non Linear Plant Along with Changing Set Point

Bharat Kumar Shamrao Patil, Laxman M. Waghmare, M. D. Uplane

Abstract: A discrete time sliding mode controller (DSMC) is proposed for higher solicitation not withstanding defer time (HOPDT) frames. As portion of structure states and botch, a sliding mode surface is selected and the tuning parameters of the sliding mode controller are resolved using overpowering post circumstance scheme. The control object for "ball in a barrel" is to handle the velocity of a fan blowing air into a chamber to keep a ball suspended in the barrel at a certain predestined position. The DSMC is attempted to coordinate the ball's position subsequently. But skillfully clear, this is a troublesome control issue due to the non-direct ramifications for the ball and the confounding material science regulating its lead. The DSMC is attempted to coordinate the ball's position subsequently. But skillfully clear, this is a troublesome control issue due to the non-direct ramifications for the ball and the confounding material science regulating its lead. The generation and experimentation results exhibit that the proposed methodology ensures needed after components. The flawlessness of current proposed framework is it stipends following of advancement continuously set point. This device to likely investigate a standard PID controller and DSMC controller. The results indicate notable separations in controllers ' implementation characteristics.

Index Terms: PID controller, SMC, DSMC, HOPDT

I. INTRODUCTION

For greater requests, a discrete time sliding mode controller (DSMC) is suggested for non-resistant defer time frames (HOPDT). As portion of structure states and botch, a sliding mode surface is selected and the tuning parameters of the sliding mode controller are resolved using overpowering post circumstance scheme. The control object for "ball in a barrel" is to handle the velocity of a fan blowing air into a chamber to keep a ball suspended in the barrel at a certain predestined position. The DSMC is attempted to coordinate the ball's position subsequently. But skillfully clear, because of the non-direct ramifications for the ball and the confusing material science that regulates its lead, this is a troublesome control issue. Additionally, the ball is incredibly sensitive to any external aggravations from the fan. Taken together, it is difficult to be compelled by the standard science, and not really got in duplicated or numerical connections of control counts. The results of the generation and experimentation show that the methodology proposed ensures that components are needed. The flawlessness of the present proposed structure is that it stipends on the continuous set point of progress. This unit is likely to explore a conventional controller for PID and DSMC. The results indicate notable separations in controllers ' implementation characteristics.

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Bharatkumar Shamrao Patil Department of instrumentation, AISSMS Polytechnic, Maharashtra, INDIA
Dr. Laxman M. Waghmare Department of instrumentation SGGS, IOT, Nanded, INDIA
Dr. M. D. Uplane Prof. Instrumentation Science Department, SP Pune, University Pune, INDIA

II. METHODOLOGY

Control action depends on the second legislation of movement of Newton. Newton's second movement law is more quantitative and is widely used to calculate what occurs in circumstances involving a force.

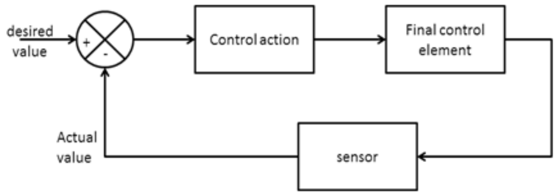

Figure1. Block diagram of proposed system

Law of Force and Acceleration states that, according to the formula net force = mass x acceleration, a force on an object causes it to accelerate. Thus the object's acceleration is directly proportional to the force and inverse to the mass.

$$\Sigma F = ma$$

a= acceleration of the object, which is velocity change per time i.e. $m/_{S^2}$

ΣF = net force on the object, SI unit is mass times acceleration, $Kg\ m/_{S^2}$ = Newton, NT

m = mass of the object

It has what we call acceleration when an object changes its velocity. Newton's second movement law offers an explanation for object conduct when applying forces. The legislation says that internal forces cause objects to accelerate, and the quantity of speed is directly

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proportional to the objects ' net power and inversely proportional to the objects ' mass. Notice that Newton's second law states that the amount of acceleration is directly proportional to the net force acting on the object. What is the net force and how do we calculate it? Net force is the sum of all forces acting on an object in a particular direction. Because forces have direction, they are quantities of vectors. With both magnitude and direction, the vector quantities are fully defined and represented with arrows. Consider an object being pushed to the left with 10 Newtons of force and to the right with 5 Newtons of force. The net force = 5 N to the left as 10 N - 5 N = 5 N. The forces are subtracted from each other since they are pointing in opposite directions. If they pointed in the same direction, the forces would be added to each other. Once the net force is determined, it is possible to determine the object acceleration.

Acceleration: When the velocity of an object changes it is said to be accelerating. Acceleration is the *rate* of change of velocity with time. Any change in the velocity of an object results in an acceleration: increasing speed (what people usually mean when they say acceleration), decreasing speed (also called deceleration or retardation), or changing direction (called centripetal acceleration).

Average acceleration is determined over a "long" time interval. The word long in this context means finite — something with a beginning and an end. The velocity at the beginning of this interval is called the initial velocity, represented by the symbol v0 (vee nought), and the velocity at the end is called the final velocity, represented by the symbol v (vee). Average acceleration is a quantity calculated from two velocity measurements.

$$\vec{a} = \frac{\Delta v}{\Delta t} = \frac{v - v_0}{\Delta t}$$

In contrast, instantaneous acceleration is measured over a "short" time interval. The word short in this context means infinitely small or infinitesimal — having no duration or extent whatsoever. It is an ideal of mathematics that can be realized only as a limit. The limit of a rate is called a derivative as the denominator approaches zero. Instantaneous acceleration is then the limit of average acceleration as the time interval approaches zero — or alternatively, acceleration is the derivative of velocity.

$$a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} = \frac{dv}{dt}$$

Acceleration is the derivative of time-speed, but velocity itself is the derivative of time-speed displacement. The derivative is a mathematical operation that can be applied to a pair of different quantities multiple times. Once you do it, you get a first derivative. Doing it twice (a derivative) provides you a second derivative. This makes speed the first speed derivative with moment and the second displacement derivative with time. $a = \frac{dv}{dt} = \frac{d}{dt}\frac{ds}{dt} = \frac{d^2s}{dt^2}$

Vectors are written in boldface in formal mathematical writing. In italics, scalars and vector magnitudes are written. Numbers, measurements, and units are written in roman (not italic, not bold, not oblique — ordinary text). For example

$$a = 9.8\ {}^{m}/_{s^2}, \theta = -90^{o}\ or$$
$$a = 9.8\ {}^{m}/_{s^2}\ at - 90^{o}$$

Another frequently used unit is the acceleration due to gravity — g. Since we are all familiar with the effects of gravity on ourselves and the objects around us it makes for a convenient standard for comparing accelerations. Everything feels normal at 1 g, twice as heavy at 2 g, and weightless at 0 g. This unit has a precisely defined value of 9.80665 m/s2, but for everyday use 9.8 m/s2 is sufficient, and 10 m/s2 is convenient for quick estimates.
The unit called acceleration due to gravity (represented by a roman g) is not the same as the natural phenomena called acceleration due to gravity (represented by an italic g). The former has a defined value whereas the latter has to be measured.

Force: A ‘Force’ is a vector quantity that can be described as a push or pull on an object resulting from the object’s interaction with another object. Whenever there is an interaction between two objects, the objects experience an equal and opposing force on each other. In other words, both the objects ‘exert force’ on each other. Force only exists as a result of an interaction. If there is no interaction, the objects no longer experience the force. Force is measured in units called Newtons (N).

Block diagram of proposed system is shown in fig 1 and described as follows:

Control action

Control action is depending on Newton’s 2nd law of motion. Force acting on an object causes the object to change its shape or size, to start moving, to stop moving, to accelerate or decelerate. When there’s the interaction between two objects they exert a force on each other, these exerted forces are equal in size but opposite in direction. When an object has several forces acting on it, the effects of force is same as one force acting on the object in a certain direction and this overall force is called the ‘resultant force’. The resultant force is essential to change the velocity of an object. Force exerted on ball is given as:

$$F_{eq} = ma = N - mg$$

$$a = \frac{F_{eq}}{m} = \frac{N - mg}{m}$$

$$F_{eq} = N - mg$$

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$$F_{eq} = N - (0.0585) * \left(9.81\ {}^{m}/_{s^2}\right)$$

So to keep the height of ball constant, we need to change 'N' such that force exerted on ball will keep the height same. To keep the ball at particular height we have to keep monitoring it and accordingly we have to adjust the volumetric flow of air.

III. SIMULATION RESULTS

Using PID and SMC control activity, reenactment results are tested. Similar computations are tried on the trial setup after reproduction with some handy preliminaries. The findings of recreation are as follows.

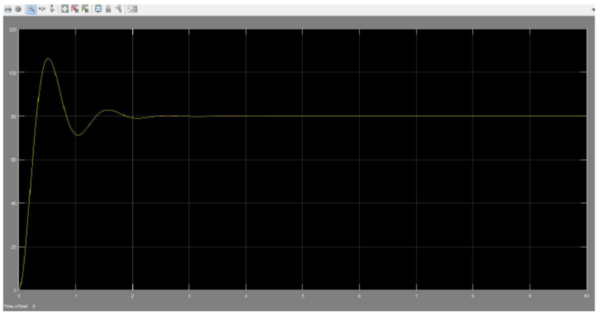

Figure2. Simulation Results using PID control action

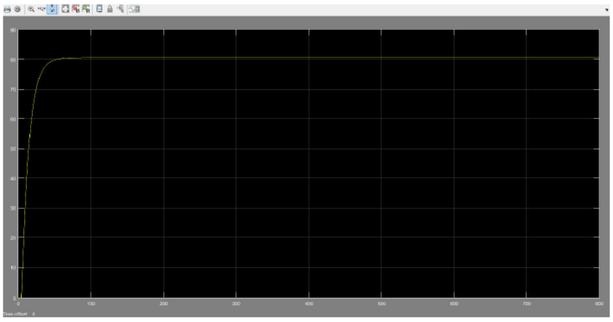

Figure3. Simulation Results using SMC control action

Figure 1 shows the simulation result of PID control action. While figure 2 reflects that of SMC control action. It gives the full idea of how SMC control action with PI sliding mode results better with suppressed damping and oscillations. Moreover, figure 3 gives idea about how tuning of SMC results in better accuracy.

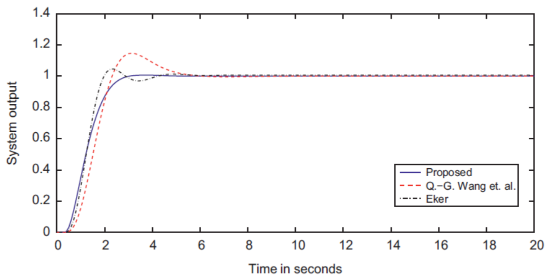

Figure4. Control signal of sliding mode control for different tuning parameter strategies

IV. EXPERIMENTAL IMPLEMENTATION

The exploratory system includes a 1 m long straight acrylic tube with a 45 mm long distance. As shown in Figure 3, the breeze current in the barrel is forced by a DC fan attached to the base end of the weight bind. Ultrasonic sensor is mounted on the most elevated purpose of the chamber so it can check the ball's position.

Ultrasonic sensors emanate a 8 cycle burst of ultrasonic sound at 40 kHz. These spread noticeable all around at the speed of sound. On the off chance that they strike a ball-in-tube, at that point they are reflected back as reverberation signs to the sensor, which itself registers the separation to the objective dependent on the time-length between producing the flag and accepting the reverberation

Figure5. actual hardware

Distance = {time-span between emitting the signal and receiving the echo} x velocity of sound / 2.

The DC blower is used to supply the air in the cylinder that is supposed to lift the ball. The wind current supplied to lift a ball is relative to the fan-connected voltage, which corresponds to the PWM signal's duty cycle. Forces applied on the ball are illustrated in figure 6. The upward applied force from the blower acting on ball-in-tube, F= - mg and downward force exerted on ball, F = mg, where 'm' is mass (here 2.7 gram is the mass of ball) and 'g' is acceleration due to gravity (9.81 m/s^2).

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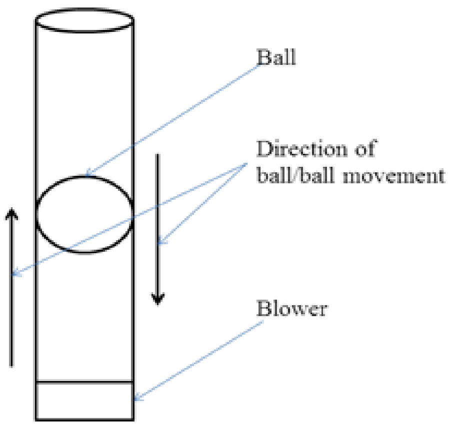

Figure6. Forces acting on ball in cylinder

For tracking of set point on experimental setup PID and SMC control action is used. It gives good tracking results. For both control actions set point is set as 60cm. Results are as shown in figure below.

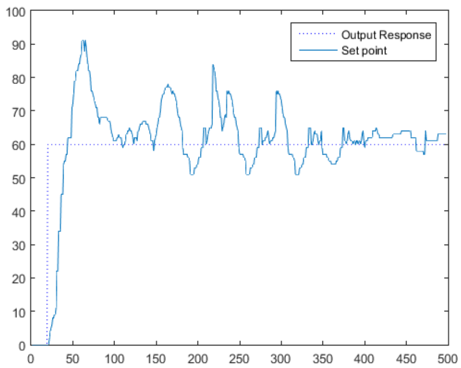

Figure7. PID control action results on experimental setup

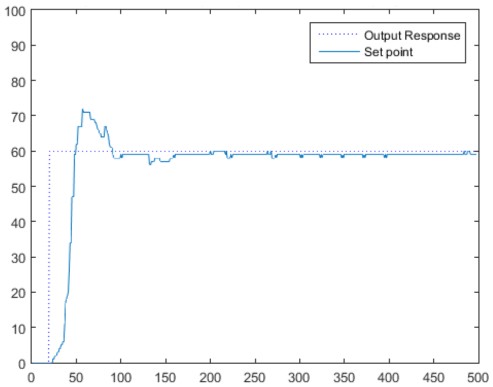

Figure8. SMC control action results on experimental setup

Experimental configuration results show that SMC control action provides outstanding precision and stability. For nonlinear and robust plant, it is the best choice. it is clear that the controller actions given by proposed SMC with PI sliding surface is smooth but PID has more chattering. On the same setup, when PID fuzzy action is tested as proposed by Ouyang Ziwei et al. the resultant response is illustrated in figure 9.

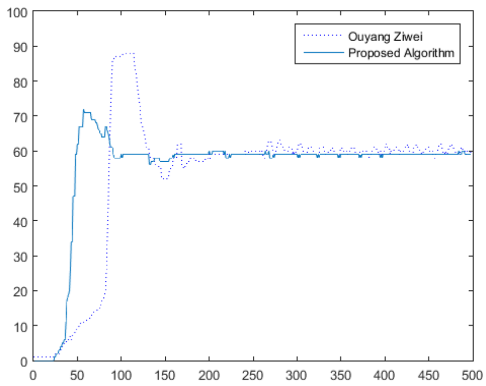

Figure9. Comparison on setup between proposed algorithm and Ouyang Ziwei

It clearly indicates that the results tested by using the Ouyang Ziwei et al. give more oscillations along with peak overshoot.

Table1. Comparison of controllers' performance

	Fuzzy PID (Ouyang Ziwei et. al.)	**Proposed SMC with PI sliding surface**
Rise time (sec)	1.06	0.9698
Settling time (sec)	5.496	3.15
Overshoot (%)	46.667	22.0339

The beauty of the proposed system is it gives the best results even for the changing set point system. It also with quick response than PID control action. The set point is set as 60 and then after some time the set point is changes to 70. Result of the same is shown in following figure.

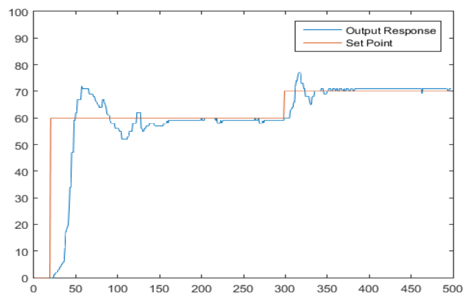

Figure10. SMC control action results on experimental setup with changing set point

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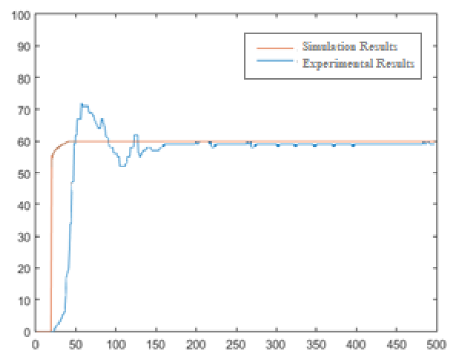

Figure11. Comparison between Simulation Results and Experimental Results

In most of the cases open loop response of the system comes out to be oscillatory. The reduced order model gains;

$$G(S) = \frac{0.0865\,3}{s^2 + 0.2701\,s + 0.413\,6}$$

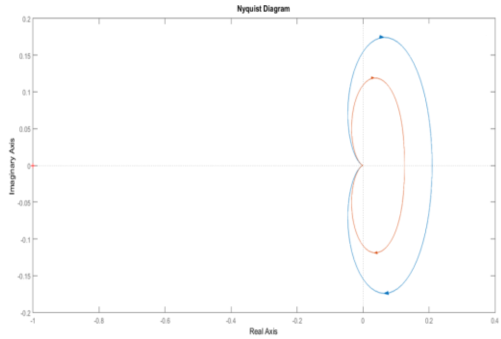

Figure12.Nyquist plot

The response of continuous time transfer function which is plotted in figure 12. The plot drawn in blue colour represents Nyquist plot of original system whereas plot drawn in red colour represents Nyquist plot of proposed system.

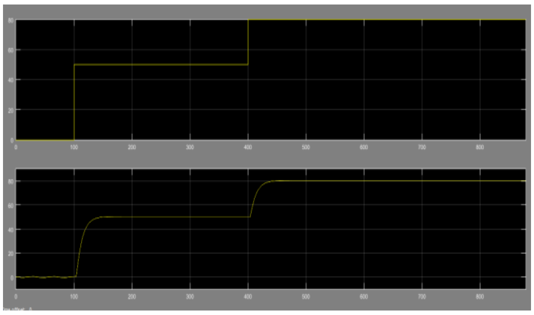

Figure13. Simulation result

Fig 12 shows step response of original and reduce order system. Simulation results shows that set point is responsible for changing characteristics of output as one can see as set point changes output waveform simultaneously changes. It results in smooth and quick results.

V. CONCLUSION

In relation to moment deferment forms by predominant post-arrangement strategy, SMC control activity with PI sliding surface is suggested for set-point following greater demand. Overpowering posts are acquired by, for example, settling time and apex overshooting from the ideal closed hover decisions. The arrangement method is obviously essential because it includes a single tuning parameter. The proposed methodology has no restrictions in regards to changing set point, framework request, time deferral, coordinating and oscillatory conduct, open circle vibration or non-least stage framework. The findings of the testing demonstrate the materiality of the ongoing application method. The movement of the controller by the proposed procedure thumps less and the expulsion of the disruptive effects is better when it stands out from the controller of the PID. The trading control law is kept in the proposed technique little to diminish motions that have an off exchange with the strength.

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