

## A Novel Adaptive Super-Twisting Sliding Mode Controller with a Single Input-Single Output Fuzzy Logic Control Based Time Varying Sliding Surface

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**Abstract:** In this study, a novel approach to the super-twisting sliding mode control of dynamic uncertain systems is proposed. The idea behind this control scheme is to utilize a time varying slope in the sliding surface function using a simple single input-single output fuzzy logic inference system so that the sliding surface is rotated in such a direction that the tracking performance of the system under control is improved. Computer simulations are performed on a system with parameter uncertainties and external disturbances. The results are compared with a conventional super twisting sliding mode controller with a fixed sliding surface. The results have shown the improved performance of the proposed approach in terms of a decrease in the reaching and settling times and robustness to disturbances and parameter uncertainties as compared to the conventional super-twisting sliding mode controller with a fixed sliding surface.

**Key words:** Sliding mode control, super-twisting sliding mode control, adaptive control, perturbation, uncertainties, chattering, fuzzy logic control, sliding surface slope, Lyapunov function, robustness

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### INTRODUCTION

Sliding mode control is a well known control scheme which has been successfully and widely applied for dynamic uncertain systems. The reason for this popularity is the attractive features of sliding mode control it is robust to external disturbances, parameter variations and uncertainties (Choi *et al.*, 1994; Young *et al.*, 1999; Eksin *et al.*, 2002; Lee *et al.*, 2003; Tokat *et al.*, 2003; Bartolini *et al.*, 2004; Boiko, 2007; Polyakov and Poznyak, 2009; Plestan *et al.*, 2010; Tao *et al.*, 2010; Chen and Lin, 2011; Fallaha *et al.*, 2011). Also, the sliding mode control method offers a simple algorithm that can be implemented easily. The sliding mode control design consists of two steps: construction of the desired sliding surface and the sliding mode enforcement. The conventional sliding mode controller uses either relay controllers or unit controllers. One of the main disadvantages of these control strategies is that due to the switching and time delays in system dynamics it is not possible for the system trajectory to reach the ideal sliding mode and therefore a high frequency oscillation called chattering occurs (Bartolini *et al.*, 1998; Boiko *et al.*, 2007; Fnaiech *et al.*, 2010; Li *et al.*, 2010). Also, the conventional sliding mode controller with a fixed sliding surface has the disadvantage that when the system states are in the reaching mode, the tracking error

cannot be controlled directly and hence, the system becomes sensitive to parameter variations (Choi *et al.*, 1994; Eksin *et al.*, 2002; Tokat *et al.*, 2003; Komurcugil, 2012).

In recent years, the super-twisting sliding mode control theory has become very popular and therefore, it has been studied widely for the control of dynamic uncertain systems. It is a second order sliding mode control and allows for finite time convergence to zero of not only the sliding variable but its derivative as well (Gonzalez *et al.*, 2012). Hence, the super-twisting sliding mode controller maintains the distinctive robust features of the sliding mode techniques while providing a control signal smoother than that obtained through the conventional first order sliding mode controller. Hence, the super-twisting sliding mode control has the advantage of less chattering compared to the sliding mode control. Moreover, super-twisting sliding mode control method offers a simple algorithm for the easy implementation as it does not require the derivatives of sliding surface function compared to the second order sliding mode controllers (Gonzalez *et al.*, 2012). However, super-twisting sliding mode controller with a fixed sliding surface has the disadvantage that the system becomes sensitive to parameter variations when the system states are in reaching mode. This sensitivity can be minimized if the reaching mode duration is minimized. Moreover, it is

tedious to find the optimum value of the sliding surface slope and it is a complicated task. A successful sliding surface design method for improving the controller performance is to use time varying sliding surfaces instead of constant ones. Thus, the method of adjusting sliding surface online is an important topic in the super-twisting sliding mode controlled systems.

During the past several years, fuzzy logic control has emerged as one of the most powerful approach for the control of dynamic uncertain systems. The main feature of fuzzy logic is its capacity to deal with imprecision, uncertainty, partial truth and approximation to achieve tractability, robustness and low cost solution. The design of fuzzy logic controller does not require the exact mathematical model of the system they are usually designed based on expert knowledge of the system (Eksin *et al.*, 2002; Pang *et al.*, 2006; Fnaiech *et al.*, 2010; Li *et al.*, 2010). Recently, fuzzy logic control has been widely used for sliding surface adjustment of the conventional first order sliding mode controllers to improve the dynamic performance and robustness (Eksin *et al.*, 2002; Tokat *et al.*, 2003; Yagiz and Hacıoglu, 2005; Komurcugil, 2012).

In this study, a new super-twisting sliding mode control scheme using a single input-single output fuzzy logic control based sliding surface adjustment is presented. The main advantage of the proposed control scheme is that the slope of the sliding surface is adjusted online according to the values of the error variables and the sliding surface moves in clockwise or anti-clockwise direction to achieve the desired performance. As the slope change is computed by a single input-single output fuzzy logic control method using one dimensional rule base the algorithm is very simple and the computation time is very less. The computer simulation results are presented to illustrate the effectiveness and robustness of the proposed control scheme over the conventional super-twisting sliding mode controller with a fixed sliding surface.

**SUPER-TWISTING SLIDING MODE CONTROL**

Super-twisting Sliding Mode Algorithm (STA) is a second order Sliding Mode Control algorithm which is a unique absolutely continuous Sliding Mode algorithm, ensuring all the main properties of first order sliding mode control for the systems with Lipschitz matched uncertainties with bounded gradients and eliminates the chattering phenomenon (Moreno and Osorio, 2008; Gonzalez *et al.*, 2012).

Unlike other second order sliding mode algorithms, super-twisting algorithm does not require the knowledge of the values of the derivatives and the knowledge of the perturbation. The research presented by Moreno and Osorio (2008) proposed a quadratic like Lyapunov functions for the super-twisting sliding mode controller, making it possible to obtain an explicit relation for the controller design parameters. The super-twisting sliding mode controller for perturbation and chattering elimination is given by:

$$v = -\alpha\sqrt{|\sigma|} \text{sign}(\sigma) - \int_0^t \beta \text{sign}(\sigma) dt \tag{1}$$

$$\alpha > \sqrt{32\delta}, \quad \beta > 5\delta \tag{2}$$

where,  $\sigma$  is the sliding surface and the unknown perturbation function  $f$  is such that  $|d/dt f(X,t)| \leq \delta$  (Polyakov and Poznyak, 2009; Gonzalez *et al.*, 2012). Consider an uncertain linear time-invariant system:

$$\dot{X} = AX + B(u + f(X, t)) \tag{3}$$

where,  $f$  is an absolutely continuous uncertainty/disturbance in Eq. 3. Assume that rank of  $B$  is  $m$  and the system is controllable and the function  $f$  and its gradients are bounded by known continuous functions almost everywhere. Then, the linear transformation:

$$\begin{bmatrix} \eta \\ \xi \end{bmatrix} = TX, \quad T = \begin{bmatrix} B^+ \\ B^- \end{bmatrix}, \quad B^+ = (B^T B)^{-1} B^T, \quad B^- B = 0$$

brings (1) to regular form given by the Eq. 4:

$$\dot{\eta} = A_{11}\eta + A_{12}\xi, \quad \dot{\xi} = A_{21}\eta + A_{22}\xi + u + \tilde{f}(\eta, \xi, t) \tag{4}$$

The idea of sliding mode control is to design the sliding variable:

$$\sigma = \xi + \lambda\eta \tag{5}$$

Such that when the motion is restricted to the manifold  $s = 0$ , the reduced order model has the required performance. The equivalent controller (Gonzalez *et al.*, 2012) is:

$$u = -\left( A_{21} + A_{22}\lambda - \lambda(A_{11} + A_{12}\lambda) \right)\eta - (A_{22} - \lambda A_{12})\sigma + v \tag{6}$$

The super-twisting sliding mode control can be obtained by using Eq. 1 and 2 in Eq. 6.

### FUZZY LOGIC CONTROL

Fuzzy logic is a powerful tool for the control of dynamic uncertain systems because of its many unique features. Fuzzy logic control is inherently robust and the design of fuzzy logic controller does not require the exact Mathematical Model of the system and does not require precise, noise free inputs. Fuzzy logic control uses defined rules governing the system and it can be modified easily to improve the performance of the system. The basic architecture of a fuzzy logic system is given in Fig. 1.

**Fuzzification:** The controller cannot use the crisp input data directly and hence there exists the need for transforming this data to the form comprehensible to the fuzzy system. This is done by fuzzification which fuzzify crisp inputs and each input is given appropriate membership value. Again, the data required to change the crisp input to the fuzzy input is stored in the knowledge base. The stored information in the knowledge base is usually the membership function associated with various linguistic variables and the rules to be fired. The heart of the whole system is this knowledge base and it has to be designed with utmost care and requires a lot of expertise in the area into which this controller is being incorporated.

**Knowledge base:** The knowledge base consists of the data base and rule base. The data base consist mainly the information required for fuzzifying the crisp inputs and rule base for defuzzifying the fuzzy outputs to a crisp output. The rule base consists of set or a table of rules which are usually formulated from the expert knowledge accumulated over a period of time (in the form of if then rules).

**Fuzzy inference engine:** Fuzzy inference engine is the execution unit. It accepts the fuzzy inputs from the

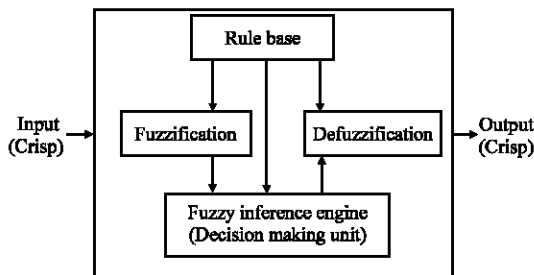


Fig. 1: Basic architecture of a Fuzzy Logic System

fuzzifier and generates fuzzified outputs after the necessary calculations. The fuzzy inference engine evaluates each rule in the rule base based on the fuzzified inputs and if this evaluation results in a non-zero output then such rules are said to be fired. Then, the inference engine combines all these outputs in accordance with a pre-specified protocol. All rules need not be equally important and each rule can be assigned a weight indicating its influence on the final output of the inference engine.

**Defuzzification:** The fuzzy outputs from the inference engine are not useful as it is and they need to be converted to crisp output and this conversion of fuzzy output to crisp output is defined as defuzzification.

### SUPER-TWISTING SLIDING MODE CONTROLLER WITH FUZZY LOGIC BASED MOVING SLIDING SURFACE

Many researchers combined the attractive features of sliding mode control and Fuzzy Logic Control (FLC) to introduce a sliding mode control based on fuzzy varying sliding surface to improve the dynamic performance and robustness (Eksin *et al.*, 2002; Tokat *et al.*, 2003; Yagiz and Hacioglu, 2005; Komurcugil, 2012). Motivated by this, it seems that fuzzy logic control can be used for sliding surface slope adjustment of super-twisting sliding mode control to improve its dynamic performance and robustness.

Consider the sliding surfaces of the super-twisting sliding mode controller given in Fig. 2. It is clear that the controller with minimum sliding surface slope leads to slower error convergence and longer tracking time whereas the controller with maximum slope leads to faster error convergence but at the cost of degrading the tracking accuracy. Therefore, there is a trade-off between tracking time and error convergence time. The rotation of

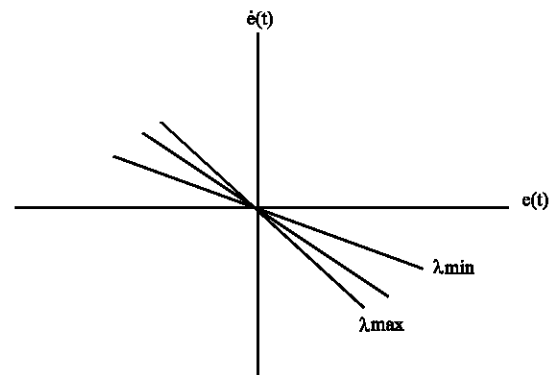


Fig. 2: Time-varying sliding surfaces

the sliding surface of super-twisting sliding mode controller can be achieved if the value of its slope  $\lambda(t)$  is updated according to the values of the error  $e(t)$  and its derivative  $\dot{e}(t)$  but with a condition that the positiveness of the slope must be preserved for ensuring the stability.

The slope of the sliding surface of super-twisting sliding mode controller can be computed by fuzzy logic inference system with  $e(t)$  and its derivative  $\dot{e}(t)$  as inputs and  $\lambda(t)$  as output using the same method of sliding surface slope adjustment of sliding mode controller proposed by Yagiz and Hacioglu (2005). Assume that error  $e(t)$  and its derivative  $\dot{e}(t)$  of super-twisting sliding mode controller are scaled down to unit range of  $[-1, 1]$  before applying them as fuzzy inputs to fuzzy logic controller.

The inputs to FLC can take negative and positive values but the output of the FLC must be positive due to the stability requirement. Hence, the rule base of the fuzzy logic controller plays a very important role and should be constructed so as to improve the performance of the system. The membership functions for the inputs  $e(t)$  and  $\dot{e}(t)$  are defined by fuzzy linguistic variables Negative Big (NB), Negative Medium (NM), Negative Small (NS), Zero (ZE), Positive Small (PS), Positive Medium (PM), Positive

Big (PB) as shown in Fig. 3 and that for the output, sliding surface slope  $\lambda(t)$  are represented by Very Very Small (VVS), Very Small (VS), Small (S), Medium (M), Big (B), Very Big (VB) and Very Very Big (VVB) as shown in Fig. 4. The rule base is given in Table 1. The two dimensional fuzzy rule has 49 rules. When the representative point falls into the second and fourth of Fig. 2, the rules are in such a manner that the sliding surface of the super-twisting sliding mode controller moves in clockwise direction.

When the representative point falls into first and third quadrants, the rules rotate the sliding surface of the controller in counter clockwise direction. Hence, with this type of rule base there is no need to shift the sliding surface up or down to make the representative point fall into second and fourth quadrants so that the time required to reach the sliding surface is reduced. However, the disadvantage of this strategy is that the rule base and computation time are considerably large.

### ADAPTIVE SUPER-TWISTING SLIDING MODE CONTROL WITH A SINGLE INPUT-SINGLE OUTPUT FUZZY LOGIC CONTROL BASED TIME VARYING SLIDING SURFACE

Komurcugil (2012) proposed a very effective method for converting two dimensional rule base of Table 1 into one dimensional rule base. Researchers propose to extend the same method for sliding surface slope adjustment of super-twisting sliding mode control.

From a careful observation of the rule base for sliding surface slope adjustment of the super-twisting sliding mode controller given in Table 1, it can be observed that the rules in each quadrant are mirror images of the rules in the adjacent quadrants. This property can be made use to reduce rule base to one dimensional rule base with absolute magnitude difference between fuzzy inputs of error  $e(t)$  and its derivative  $\dot{e}(t)$  forming a single input and slope of super-twisting sliding mode controller  $\lambda(t)$  as the output (Komurcugil, 2012). Researchers define a new variable  $e_d(t)$  which is the magnitude difference in error variables, i.e.:

$$e_d(t) = |e(t)| - |\dot{e}(t)| \tag{7}$$

Assume that  $e_d(t)$  is scaled down to unit range of  $[-1, 1]$  before applying it as fuzzy input to fuzzy logic controller. The membership functions for the input are represented by Negative Big (NB), Negative Medium (NM), Negative Small (NS), Zero (ZE), Positive Small (PS), Positive Medium (PM), Positive Big (PB) as shown in Fig. 3 and those of output  $\lambda(t)$  are Very Very Big (VVB), Very Big (VB), Big (B), Medium (M), Small (S), Very Small

Table 1: Two dimensional fuzzy rule base

$e(t)/\dot{e}(t)$	NB	NM	NS	ZE	PS	PM	PB
NB	M	B	VB	VVB	VB	B	M
NM	S	M	B	VB	B	M	S
NS	VS	S	M	B	M	S	VS
ZE	VVS	VS	S	M	S	VS	VVS
PS	VS	S	M	B	M	S	VS
PM	S	M	B	VB	B	M	S
PB	M	B	VB	VVB	VB	B	M

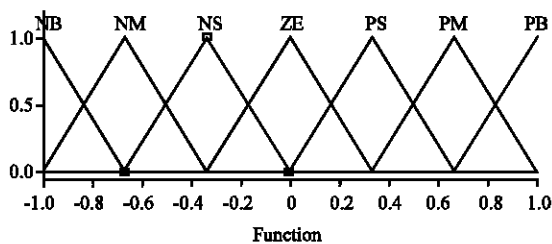


Fig. 3: Input membership functions

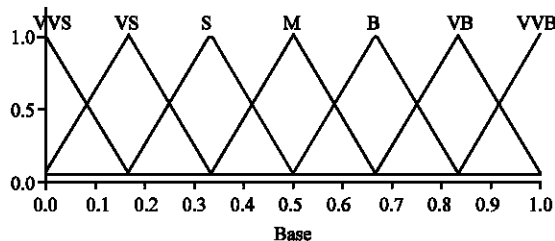


Fig. 4: Output membership functions

Table 2: One dimensional fuzzy rule base

Membership function	Out put
$e_3(t)$	$\lambda(t)$
NB	VVB
NM	VB
NS	B
ZE	M
PS	S
PM	VS
PB	VVS

(VS), Very Very Small (VVS) as shown in Fig. 4. The one dimensional rule base to compute slope  $\lambda(t)$  is given in Table 2.

The Centroid Method can be used for defuzzification. Obviously, the calculation of the time varying slope of the super-twisting sliding mode controller is less complicated compared to the case of having a two dimensional rule base. The proposed controller is the super-twisting sliding mode controller given by Eq. 1 with sliding surface varying based on the error variables. Polyakov and Poznyak (2009) proposed the condition for the stability of the super-twisting sliding mode controller with a fixed sliding surface as given in Eq. 2. Since, the sliding surface of the proposed controller is time-varying, the positiveness of the sliding surface slope  $\lambda(t)$  must be preserved for ensuring the stability. Hence, the parameters of the proposed controller can be designed so that they satisfy Eq. 8:

$$\alpha > \sqrt{32\delta}, \quad \beta > 5\delta, \quad \lambda(t) > 0 \quad (8)$$

### SIMULATIONS

**Model description:** A mass-spring-damper system consists of two masses, three springs, one damper as shown in Fig. 5. The dynamics of the system is:

$$\dot{x}_1(t) = x_2(t) \quad (9)$$

$$\dot{x}_2(t) = \frac{(K_1 + K_2)}{M_1} x_1(t) + \frac{K_2}{M_1} x_3(t) + \frac{1}{M_1} F(t) \quad (10)$$

$$\dot{x}_3(t) = x_4(t) \quad (11)$$

$$\dot{x}_4(t) = \frac{K_2}{M_2} x_1(t) - \frac{(K_2 + K_3)}{M_2} x_3(t) - \frac{B}{M_2} x_4(t) \quad (12)$$

Where:

- $x_1(t)$  and  $x_3(t)$  = The positions
- $x_2(t)$  and  $x_4(t)$  = The velocities of masses  $M_1$  and  $M_2$ , respectively
- $F(t)$  = The input force to mass  $M_1$

Nominal values for the parameters are  $M_1 = 1.28$  kg,  $M_2 = 1.05$  kg,  $K_1 = 190$  N m<sup>-1</sup>,  $K_2 = 780$  N m<sup>-1</sup>,  $K_3 = 450$  N m<sup>-1</sup>,  $B = 15$  N sec m<sup>-1</sup>. The control objective is to maintain the position of mass  $M_1$  fixed at  $x_1(t) = x_{1d}$  despite of the behavior of mass  $M_2$  that can be considered as a perturbation. The change of co-ordinates given by Eq. 13 brings mass but system to regular form:

$$\eta = \frac{1}{m_1}(x_1 - x_{1d}), \quad \xi = m_1 x_2 \quad (13)$$

**Control design:** The linear sliding surface given by Eq. 14 is selected so that the equilibrium point will be reached exponentially fast and with a desired performance:

$$\sigma = \xi + \lambda \eta \quad (14)$$

The equivalent control is:

$$u = -\frac{\lambda}{M_1^2}(-\lambda \eta + \sigma) + K_1 M_1 \eta + K_1 x_{1d} + v \quad (15)$$

where,  $v$  is the super-twisting control given by Eq. 1. The upper bound of the derivative of the perturbation is:

$$\delta = K_2 (|x_{4max}| + |x_{2max}|) \quad (16)$$

By detailed analysis and simulation of the system, it is found that  $|x_{4max}| = |x_{2max}| = 0.02$  m sec<sup>-1</sup>. Hence, the controller gains are selected as  $\alpha = 40$  and  $\beta = 200$  so that they satisfy Eq. 8. The sliding surface slope of the proposed controller is computed online using single input-single output fuzzy logic controller as explained in the study. The input and output scaling factors of fuzzy logic controller are 100 and 3.9, respectively.

**Simulation results:** For comparison, two different controllers are simulated using MATLAB, the proposed adaptive super-twisting sliding mode controller using fuzzy logic based time varying sliding surface and the super-twisting sliding mode controller with a fixed sliding surface slope  $\lambda = 1.95$  (the steady-state value of the sliding surface slope for the proposed controller). For the simulations at time  $t = 0$ , a reference position  $x_{1d} = 0.01$  m is demanded. The simulation results are given in Fig. 6-11. The performance measures such as steady-state error, time taken for the output to reach 90 and 100% of the steady-state value, percentage overshoot and integral of time Multiplied Absolute Error (ITAE) are used to compare the performances of the controllers. The comparison is given in Table 3. In case of the proposed

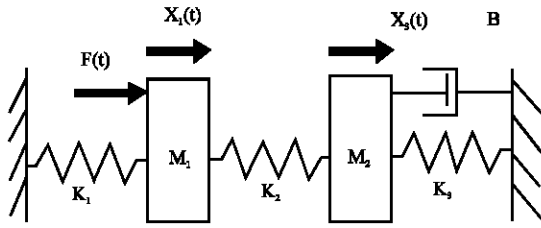


Fig. 5: Mass-Spring-Damper System

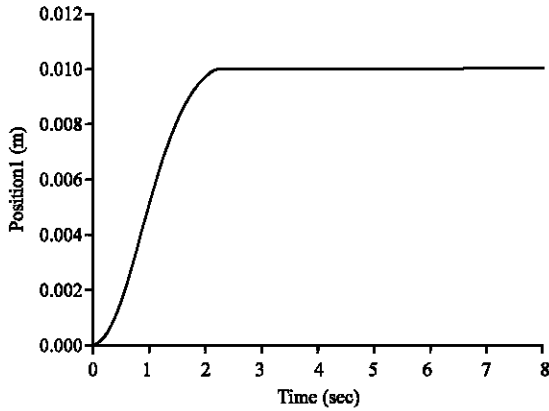


Fig. 6: Position of mass  $M_1$  using the proposed controller

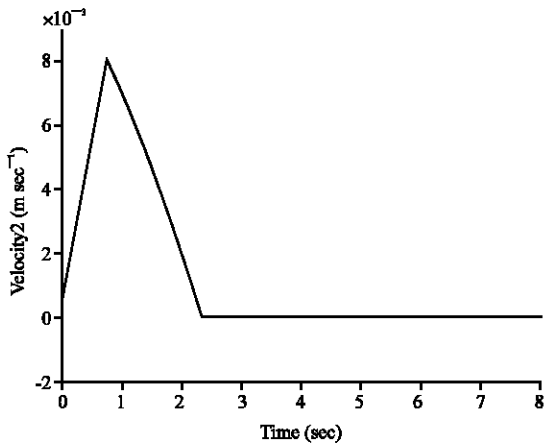


Fig. 7: Velocity of mass  $M_1$  using the proposed controller

controller, the time taken to reach 90% of the steady-state value and is 1.75 and that for the steady-state value is 2.27 sec whereas in case of the conventional super-twisting sliding mode controller with a fixed sliding surface they are 1.84 and 4.77 sec, respectively. The overshoot and steady-state error are zero in both the cases. The integral of Time Multiplied Absolute Error (ITAE) for the proposed controller and the conventional super-twisting sliding mode controller with a constant sliding surface are 0.0064 and 0.0083, respectively. From the comparison, it is clear that both the controllers are

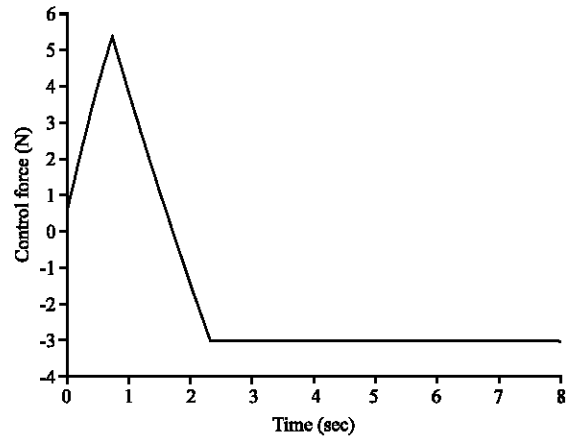


Fig. 8: Control force of mass  $M_1$  using the proposed controller

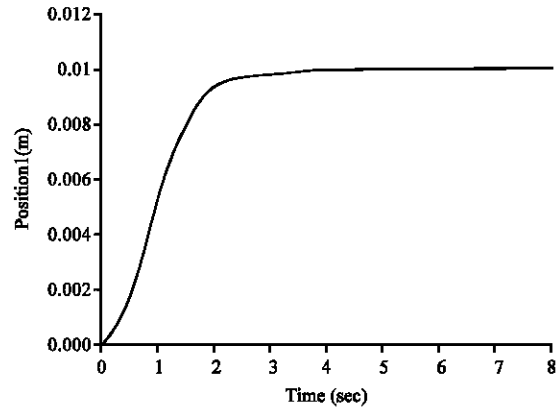


Fig. 9: Position of mass  $M_1$  using the super-twisting sliding mode controller with a fixed sliding surface

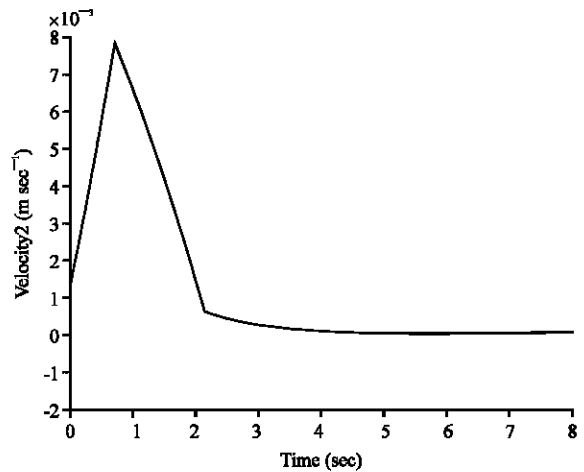


Fig. 10: Velocity of mass  $M_1$  using the super-twisting sliding mode controller with a fixed sliding surface

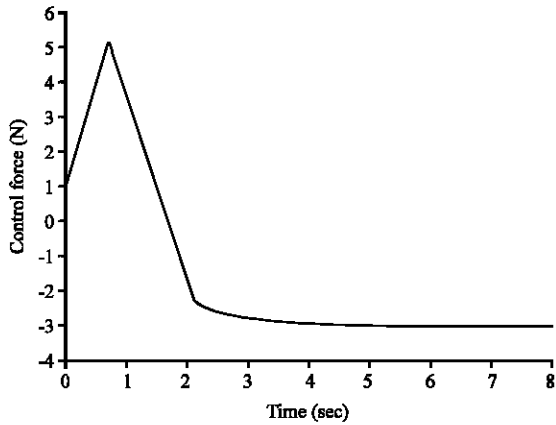


Fig. 11: Control force of mass  $M_1$  using the super-twisting sliding mode controller with a fixed sliding surface

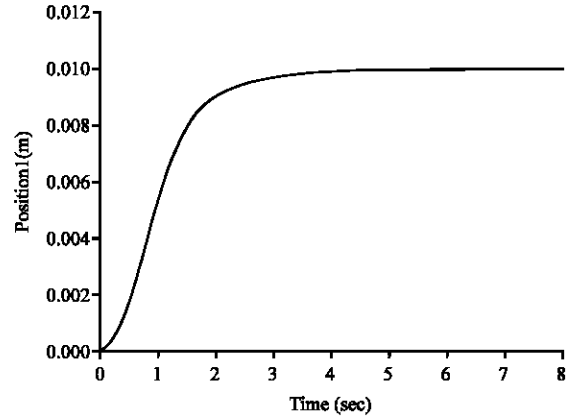


Fig. 12: Position of mass  $M_1$  using the proposed controller for spring constant  $K_1$  equal to  $150 \text{ N m}^{-1}$

Table 3: Comparison of the performances of controllers

Output	Proposed controller	Super-twisting sliding mode controller with a fixed sliding surface
Time taken to reach 90% of the steady-state value (sec)	1.75	1.84
Time taken to reach the steady-state value (sec)	2.27	4.77
Percentage overshoot	0	0
Steady-state error	0	0
IATE	0.0064	0.0083

able to achieve the objective but the proposed controller as an indication of shortening the reaching mode time, thereby improving the robustness compared to super-twisting sliding mode controller with a constant sliding surface.

To study the robustness of the proposed controller, the parameter variations in the form of changes in spring constant of  $K_1$  of the system are considered. The responses of the system using the proposed controller and the conventional super-twisting sliding mode controller with a fixed sliding surface for  $K_1 = 150 \text{ N m}^{-1}$  are given in Fig. 12 and 13, respectively. In case of the proposed controller, the time taken to reach 90% of the steady-state value and is 1.99 sec and that for the steady-state value is 5.35 sec whereas in case of the conventional super-twisting sliding mode controller with a fixed sliding surface, they are 2.18 and 5.7 sec, respectively. The overshoot and steady-state error are zero in both the cases.

The Integral of Time Multiplied Absolute Error (ITAE) for the proposed controller and the conventional super-twisting sliding mode controller with a fixed sliding surface slope are 0.01 and 0.012, respectively. Both the controllers are able to reject the effect of parameter variation without any overshoot

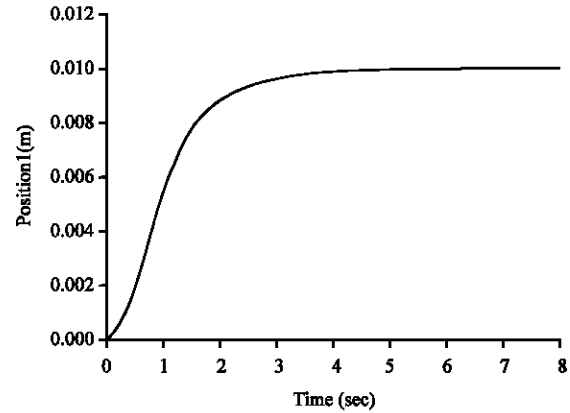


Fig. 13: Position of mass  $M_1$  using the super-twisting sliding mode controller with a fixed sliding surface for spring constant  $K_1$  equal to  $150 \text{ N m}^{-1}$

but the proposed controller shows faster response. The responses of the system using the proposed controller and the conventional super-twisting sliding mode controller with a fixed sliding surface for  $K_1 = 230 \text{ N m}^{-1}$  are given in Fig. 14 and 15, respectively. In case of the proposed controller, the time taken to reach 90% of the steady-state value and is 1.7 sec and that for the steady-state value is 4.7 sec whereas in case of the conventional super-twisting sliding mode controller with a fixed sliding surface they are 1.74 and 5.6 sec, respectively, the overshoots are 9.45 and 10.1%, respectively. The steady-state errors are zero in both the cases.

The Integral of Time Multiplied Absolute Error (ITAE) for the proposed controller and the conventional super-twisting sliding mode controller with a fixed sliding surface are 0.009 and 0.0098, respectively. Again, the

Table 4: Comparison of the performances of controllers for variations of  $K_1$

Variations of $K_1$	Output	Proposed controller	Super-twisting sliding mode controller with a fixed sliding surface
$K_1 = 150 \text{ N m}^{-1}$	Time taken to reach 90% of the steady-state value (sec)	1.99	2.18
	Time taken to reach the steady-state value (sec)	5.35	5.7
	Percentage overshoot	0	0.0
	Steady-state error	0	0.0
	IATE	0.01	0.012
$K_1 = 230 \text{ N m}^{-1}$	Time taken to reach 90% of the steady-state value (sec)	1.7	1.74
	Time taken to reach 100% of the steady-state value (sec)	4.7	5.6
	Percentage overshoot	9.45	10.1
	Steady-state error	0	0.0
	IATE	0.009	0.0098

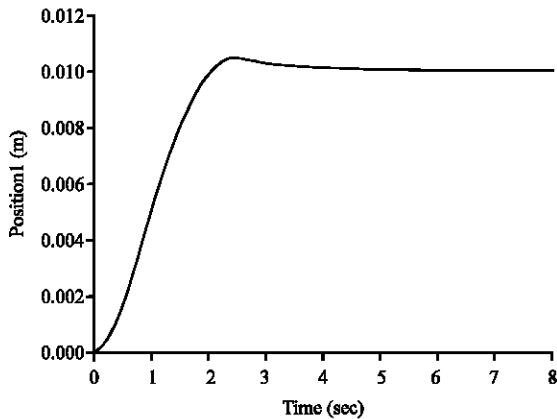


Fig. 14: Position of mass  $M_1$  using the proposed controller for spring constant  $K_1$  equal to  $230 \text{ N m}^{-1}$

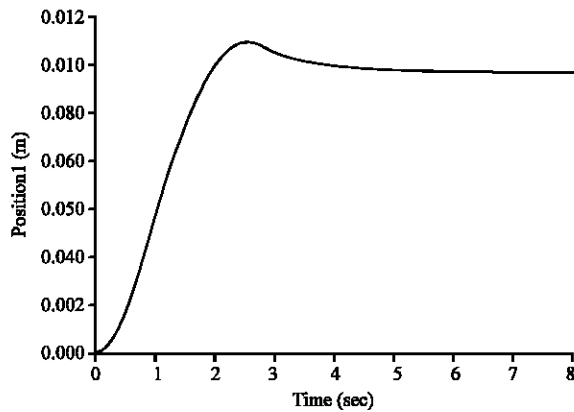


Fig. 15: Position of mass  $M_1$  using the super-twisting sliding mode controller with a fixed sliding surface when spring constant  $K_1$  equal to  $230 \text{ N m}^{-1}$

proposed controller outperforms the conventional controller with less overshoot and faster dynamics. The comparison of the performances of the controllers for different variations of  $K_1$  is given in Table 4.

### CONCLUSION

In this study, a new super-twisting sliding mode control using a single input-single output fuzzy logic controller based sliding surface adjustment is proposed. It is shown that the dynamic response and the robustness of the controller can be improved by rotating the sliding line in phase plane by a simple single input-single output fuzzy logic control. The effectiveness of the proposed approach is demonstrated through simulation results using a dynamic uncertain system. The simulation results show that the proposed controller exhibits fast dynamic response and it can be considered as an indication of shortening the reaching mode time thereby improving the robustness compared to super-twisting sliding mode controller with a fixed sliding surface. The robustness of the proposed controller is studied for parameter variations. The results show that the proposed controller outperforms the conventional super-twisting sliding mode control with a fixed sliding surface in terms of improved dynamic response and robustness. Moreover, the proposed control scheme is very simple, computation time is very less and easy to implement.

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