International Journal of Advances in Engineering and Management (IJAEM)
Volume 2, Issue 1, pp: 241-252 www.ijaem.net ISSN: 2395-5252

Wearable Exoskeleton Assisted Rehabilitation in Multiple Sclerosis by Using Back Stepping Sliding Mode Control Techniques

Budda Purushotham[1], V Sunil Kumar Reddy[2]
[1]*Student, MJR College of Engineering and Technology, Piler, Andhra Pradesh.*
[2]*Assistant Professor, MJR College of Engineering and Technology, Piler, Andhra Pradesh.*

Date of Submission: 10-06-2020 Date of Acceptance: 26-06-2020

ABSTRACT: A humanoid robot walking model with RH-2 can perform distinctive assignments in a joint effort by using PID controller different values of human in working environments is presented in this paper. Human-robot coordinated effort has a regular edge work as for human-robot association. In human-robot, we are using the linear control system to single inverted pendulum. In humanoid stride is frequently displayed with different forms of the modified pendulum, for example, 2D and 3D linear reversed pendulums. A human-robot is using the direct control system to using trial and error method using with PID controller and without PID controller in different values. By using humanoid-robot RH-2, the walking control was tested successfully. Contextual analysis is exhibited all together human-robot test platform humanoid-robot RH-2. They provide a high adaption to changing conditions and have the ability to make decisions quickly by processing imprecise information. Sliding mode control (SMC) reaction is superior to BACKSTEPPING SLIDING MODE CONTROLLER reaction to various unsettling influences. We accomplish great following of joint removals and speeds for both ostensible and irritated estimations of the framework parameters.

KEYWORDS: Humanoid-robot, non-linear control, tracking and disturbance rejection.

I. INTRODUCTION

We would like to beat this delicacy during the time spent structure up a running humanoid [1, 2]. Human-like walk and imperativeness use are two of the main segments to be thought of while arranging powerful biped humanoid robots [3]. Most examinations centre around biped strolling. Survey those productive showings, we normally expected to ask we fabricate a running humanoid [4]. We believe it is a beneficial specific test for going with reasons. In any case, the examination of running will add new components of movability to humanoid robots. Current robots are too fragile to even think about evening consider working in various conditions. We should treat them carefully even in an investigation of walking around low speed.

Field mechanical innovation in real life and backing can be possible using flight control through an unscrewed self-overseeing helicopter. The section of flying electrical link evaluation provoking is acknowledgment and avoidance. There are various considerations in the arrangement of electrical link robots taking a shot at engaged lines. The ability to come, live conductors, is the rule feature to be thought of to make this possible, the parts in the mechanical arrangement need to withstand the effect of strong electromagnetic fields. Running robots have been genuinely analyzing [5], their notable bouncing robots driven by pneumatic and water-fueled actuators performed various exercises including a couple of results using without and with PID controller. To control abundance robots is comprehensively utilized humanoid mechanical self-governance, and furthermore its accomplice in the force zone, the operational space approach. This prompts gigantic and overweight’s the actuators and batteries concerning their solid use.

One of the principal upgrades to RH-2 with respect to its predecessor is the arrangement of the lower leg. The lower leg is basic when overseeing walking exercises and quality. The benefits of electrical link mechanical innovation will be in a full length just on the off chance that it goes practically identical to the human's utilization without replacing him at work. The whole structure goes about as a changed the tip mass of the pendulums gathered at the robot's motivation of the focal point of mass (COM). The control configuration proposed has been taken endeavored at using the model of RH-2.

Practically speaking, numerous nonlinear procedures are approximated by decreased request models, which may be straight, which is plainly connected with the basic procedure qualities. In any case, these models might be legitimate just inside certain unequivocal working extents, and various models might be required in the wake of changed performing conditions, or the control framework should grasp the new framework model parameters. The appearance of a sliding mode controller (SMC) procedures, for example, neural systems, has settled this issue as it were. The neural innovation permits a lot more focal points in the territory of non-control issues, especially when the framework is working over the non-direct working extent.

The sliding mode controller (SMC) utilizing the distinctive unsettling influences varieties of vital square error (ISE). SMC utilizes the increase and distinctive unsettling influences to include a few cases for virtual diagrams. In control frameworks, sliding mode control (SMC) is a nonlinear control strategy that modifies the elements of a nonlinear framework by utilization of a broken control sign (or all the more thoroughly, a set-esteemed control signal) that powers the framework to "slide" along a cross-segment of the framework's ordinary conduct. The state-input control law is certifiably not a ceaseless capacity of time. Rather, it can change starting with one consistent structure then onto the next dependent on the present situation in the state space. Consequently, sliding mode control is a variable structure control strategy.

An ideal sliding mode exists only when the system state satisfies the dynamic equation that governs the sliding mode foe all time. This requires an infinite switching in general, to ensure the sliding motion. Sliding mode control (SMC) is a nonlinear control technique featuring remarkable properties of accuracy, robustness, and easy tuning and implementation. SMS systems are designed to drive the system states onto a particular surface in the state space, named sliding surface. The addition misfortunes for the SMC and PID are too shifted the all-out number of unsettling influences to best reactions is SMC. The distinctions about diagrams were to better for SMC to BACKSTEPPING SMC.

As needs are, to reflect fine powers, for instance, the contact and sliding intensity of tele surgery, the components of the pro robot should be compensated for authentically. Three DOF haptic interfaces have been used for the expert robot, and another flexible impedance control computation has been made to reflect the analysis drive with respect to the components of the haptic interface. Most biped robots set up in all actuality are made out of a lot of interconnected joints, and the dynamic equality and position ought to be considered simultaneously. Taking everything into account, non-straight biped systems are a champion among the most problematic control issues in the arrangement. Inferable from the flightiness of the three degrees of chance (DOF) arrangement of humanoid robots, a natural and beneficial strategy for whole-body control is required. Regardless, how to improve the accompanying execution of biped robots through arranged controls is up 'til now a testing research topic that pulls in phenomenal thought from the mechanical independence system to better for SMC to BACKSTEPPING SMC.

The human walk is much of the time showed with various types of the switched pendulum, for instance, 2D and 3D direct adjusted pendulums (LIP) [6-9]. Sensor mix difficulties in sensor mix and information planning. Join different distinguishing capacities into little, low-control, consistent planning subsystems. Here we present a novel structuring named F-IVT (Flywheel-Infinitely Variable Transmission) actuator that on a first measurement permit to man-handle the characteristics of the lower part progression smoothing out the working conditions of the electric motor and vanquishing the starting late referenced issues [10-12]. Overseeing existing live line working strategies and standard hotline equipment is another technique for controlling the advancement. This requires the foundation of an electrical link examination robot on the invigorated line inside 30 minutes of falling off the structure.

A couple of models can be used to accomplish unfaltering quality. A piece of those relies on the computation of ZMP [13-14]. A point concerning which the dynamic reaction adds to the contact of feet with the ground doesn't make any moment, i.e., a position where show dormancy push is proportionate to zero. The virtual granny walker spring damper constants probably vacillated while truly taking a gander at their effects. Walking was begun in the main assistance stage. A slight push was associated with the robot to drive it forward [15]. After the push, no outside intervention was required. An organization robot is which works semi or totally autonomously to perform organizations important to the flourishing of individuals and equipment, notwithstanding manufactures exercises. The Zero Momentum Point (ZMP) estimation is moreover basic for the semi-online assessment of ZMP improvement. In case pro's goals are known early, the correct model can be chosen for arms and legs.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 2, Issue 1, pp: 241-252 www.ijaem.net ISSN: 2395-5252

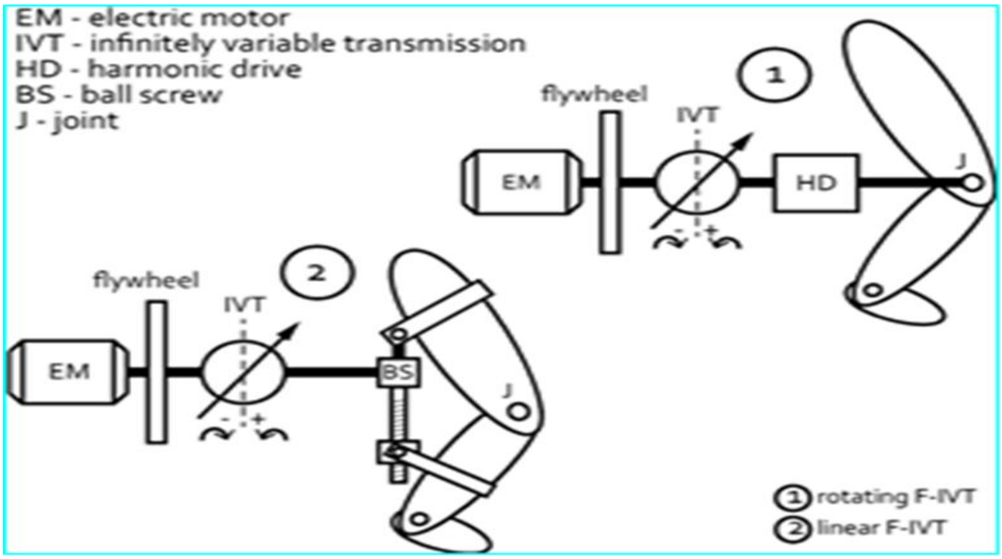

Fig. 1. Schematic diagram of the F-IVT architectures

The human-robot joint exertion has a normal framework for human-robot correspondence. The humanoid walk is as often as possible showed with various types of the modified pendulum, for instance, 2D and 3D straight annoyed pendulums [16-17]. The single modified pendulum associated with the robot and the test shows M(S) of the lower leg actuator.

Single inverted pendulum

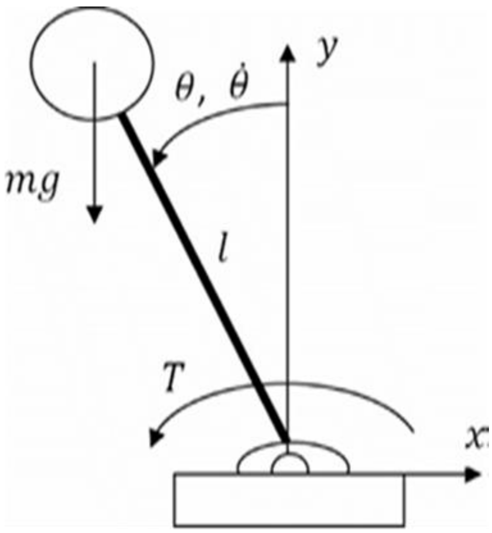

Fig. 2. Single inverted pendulum

Where 'g' is denoted as gravitational acceleration, 'T' – input torque and 'Θ' is position angle, 'm'- a mass of the motor and l is the length of the link.

The distinctive virtual spring, damper and force factors, and walking parameters were picked using the physical understanding and a manual interest. The virtual granny walker spring damper constants have likely vacillated while truly taking a gander at their things. Walking was begun in the main assistance stage [18]. A slight push was associated with the robot to drive it forward. Additionally, the action (control torque T) that empowers the mass m to move a positive edge Θ at speed is influenced by a servomotor (chop down the leg of the humanoid robot) settled toward the climax of the connection (floor) [19]. This servomotor plays out the control improvement to ensure the consistency of the structure in the midst of the walking movement.

Figure 2 is speaking to a solitary reversed pendulum model. This model isn't sufficiently stunning to show the entire pieces of the humanoid robot and to consider its nonlinearities [20]. Regardless, as can be checked ahead of time remaining in contact with, it gives astounding outcomes, even likely, as a first estimate [21]. There is hopping gravitational force proportional to mg, where g is the expanding pace considering gravity. There is, in addition, a frictional force revoking the progression, which we see to concern the speed of the tip with breaking down coefficient k.

Using Newton's second law of progress, we can make the condition out of headway the digressive route as

$$ml\theta^{11} = -mg\sin\theta - kl\theta^{1} \quad (1)$$

Composing the condition of movement toward this path has a favorable position that the connection strain, which is the typical way, does not show up in the condition. So as to acquire a state demonstrate for the pendulum, let us accept the state factors as $x_1 = \theta, x_2 = \theta^1$. Then, the state equations are defined as

$$x_1^1 = x_2$$
$$x_2^1 = -\frac{g}{l}\sin x_1 - \frac{k}{m}x_2 \quad (2)$$

From the physical portrayal of the pendulum obviously, it has just two balance positions comparing to the balance focuses (0, 0) and (π, 0).

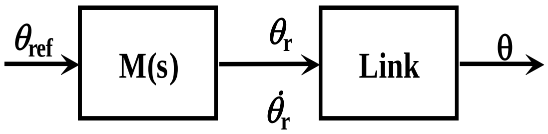

Fig. 3. Posture control system

Substantially, the positions of the pendulum are extremely specific from each other. While the pendulum can without a doubt rest at the (0, 0) harmony point, it might be not by any stretch of the imagination kept up at the (π, 0) point in light of the fact that subtly little irritation from that parity will expel the pendulum. The modification between the two affability centers is in reliability properties

This torque is seen for our circumstance as a controlling commitment to condition.

$$x_1^1 = x_2,$$
$$x_2^1 = -\frac{g}{l}\sin x_1 - \frac{k}{m}x_2 = \frac{1}{ml^2}T \quad (3)$$

SMC CONTROLLER

We performed generations with 1% to half get exacerbation parameter deviations, and we saw that the following execution remained accurate. It is seen from the propagation results that following of robot controller by considering a sliding mode controller (SMC) strategy gives the least objective work. SMC gives the least after slip-up and extraordinary exacerbation excusal appeared the headings remained inside their cutoff layers after the alteration time period, which realized the incredible quality and following execution.

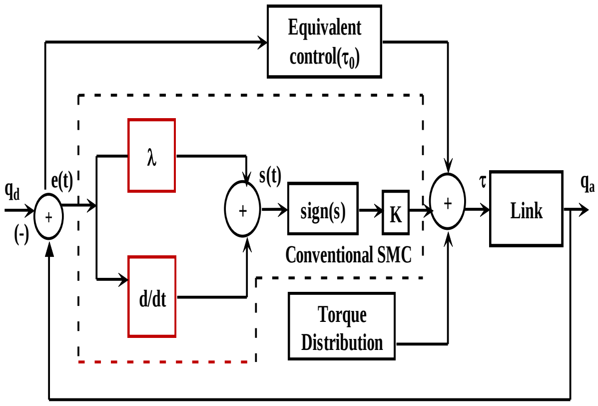

Fig. 4. Block diagram of the conventional sliding mode control

The robot manipulator of total control torque is

$$\tau = \tau_0 + \tau_c \quad (4)$$

Where τ_0 is equivalent control torque, 'τ_c' is control torque of sliding mode . sliding surface 's' is

$$s = \dot{e} + \lambda e \quad (5)$$

Where λ is positive constant. The main aim of this method is to keep 's' near to zero. The purpose of SMC is to force tracking error 'e' to approach the sliding surface and then move along the surface to the origin. The derivative of sliding surface concerning time can be expressed as follows:

$$\dot{s} = \ddot{e} + \lambda \dot{e} \quad (6)$$
$$\ddot{s} = \ddot{q}_d - \ddot{q} + \lambda \dot{e} \quad (7)$$

Where $\ddot{e} = \ddot{q}_d - \ddot{q}$

Finally, τ_c is the reaching control signal as follows

$$\tau_c = K * sign(s) \quad (8)$$

The sliding mode controller has been prepared with full state-input just as with inadequate state criticism. The quantity of informational indexes utilized for preparing has been fluctuating (from around 50 to 100) for various models. For every robot leg model, the best-prepared system has been held as the controller and it has been for all time spared as a MATLAB record called the net. At long last, the exhibition of the SMC of the time area details i.e., direction following and unsettling influence dismissal.

TABLE: I SMC TUNING parameters ewith 1% disturbances.

S.No	SMC CONTROLLER		
	LMD	**K**	**ISE**
1	15	5	0.02373
2	30	10	0.002882
3	50	4	0.004304
4	60	7	0.001777
5	70	9	0.00197
6	80	11	0.002678

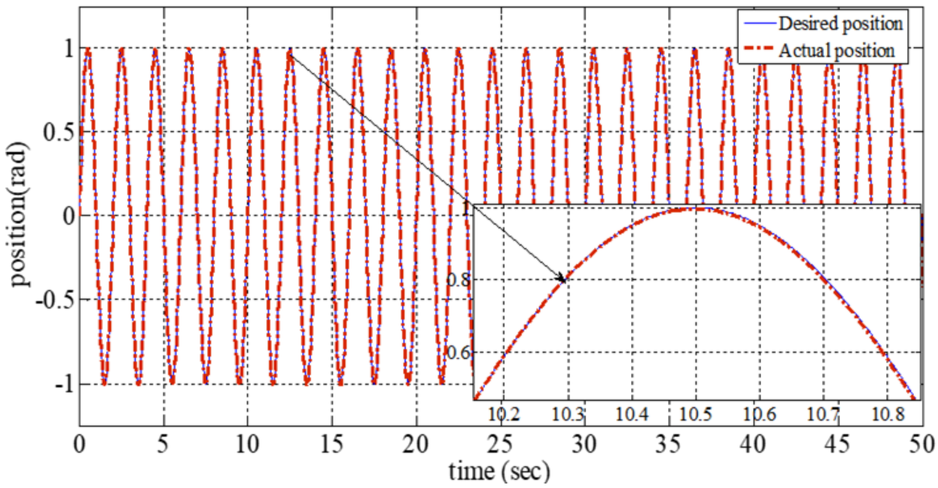

Fig 5 Tracking Positions of SMC for various 1% disturbances

Table 2 SMC TUNING parameters with 2% disturbances.

S.NO	SMC CONTROLLER		
	LMD	K	ISE
1	5	5	0.4411
2	12	12	0.01265
3	25	15	0.003975
4	40	19	0.005867
5	55	28	0.01473
6	65	34	0.02324

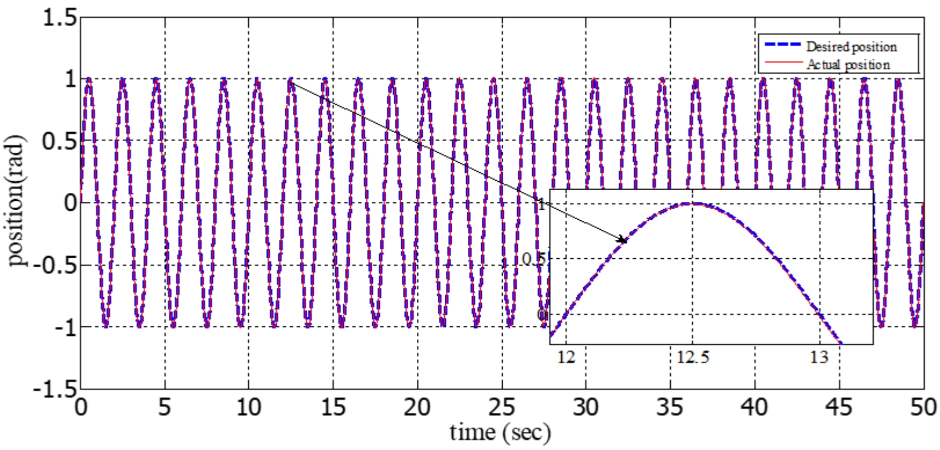

Fig 6 Tracking Positions of SMC for various 2% disturbances

Table 3 SMC TUNING parameters with 3% disturbances.

S.NO	SMC CONTROLLER		
	LMD	K	ISE
1	7.5	3	0.2361
2	15	6	0.01526
3	22.5	9	0.004143
4	30	12	0.003018
5	37.5	15	0.00383
6	45	18	0.005745

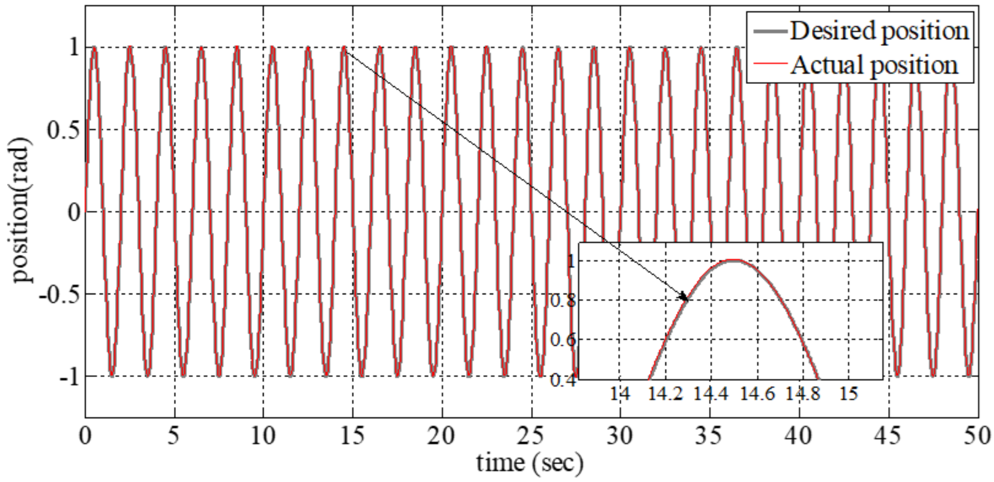

Fig 7 Tracking Positions of SMC for various 3% disturbances

Table 4. SMC TUNING parameters with 10% disturbances.

S.NO	SMC CONTROLLER		
	LMD	K	ISE
1	20	12	0.003647
2	30	18	0.004789
3	35	14	0.003238
4	38	13	0.003015
5	25	8	0.004157
6	16	11	0.005041

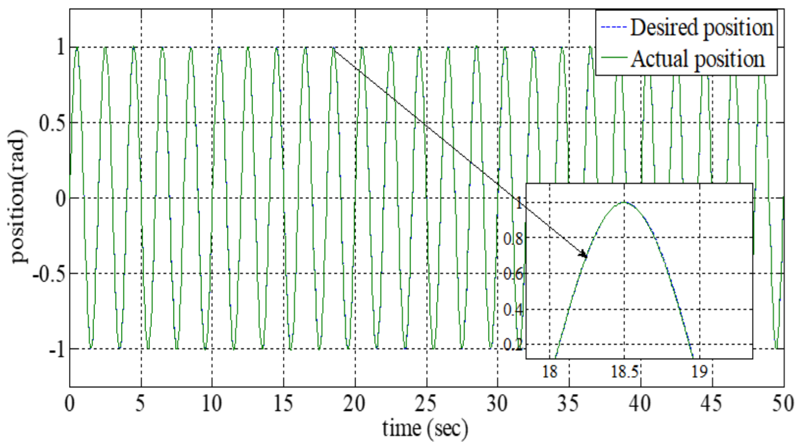

Fig 8 Tracking Positions of SMC for various 10% disturbances

Table 5. SMC TUNING parameters with 30% disturbances.

S.NO	SMC CONTROLLER		
	LMD	K	ISE
1	17	17	0.00432
2	24	24	0.009383
3	30	30	0.01621
4	38	38	0.02775
5	47	47	0.04505
6	54	54	0.04867

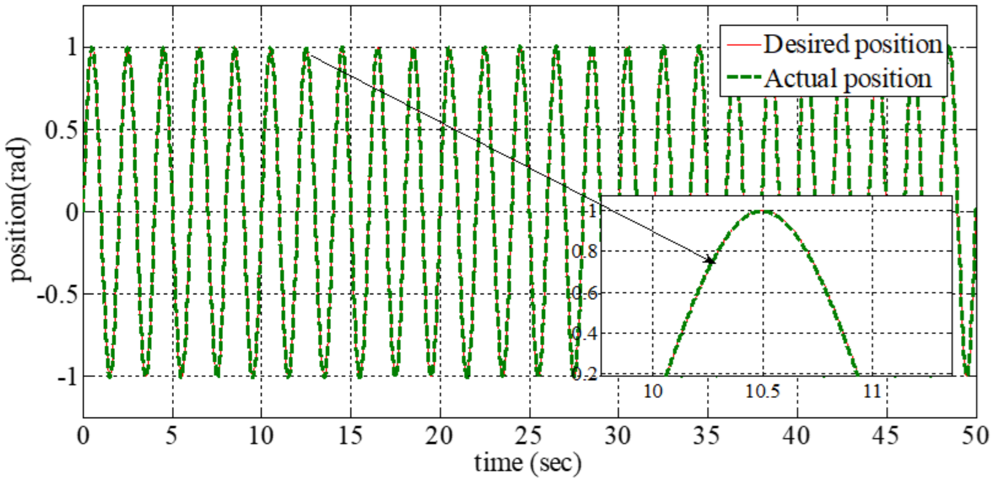

Fig 9 Tracking Positions of SMC for various 30% disturbances

Table 6. SMC TUNING parameters with 50% disturbances.

S.NO	SMC CONTROLLER		
	LMD	K	ISE
12	16	6	0.01407
2	21	12	0.003455
3	34	19	0.005188
4	45	23	0.008775
5	60	29	0.01592
6	75	34	0.02364

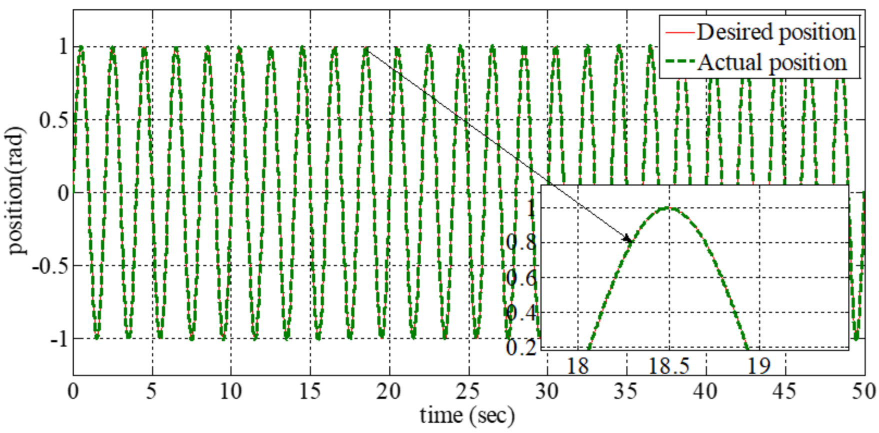

Fig 10 Tracking Positions of SMC for various 50% disturbances

BACKSTEPPING SLIDING MODE CONTROLLER (BSMC)

A basic back stepping sliding mode controller is proposed for controlling under actuated frameworks. The back stepping calculation makes the controller insusceptible to coordinated and jumbled vulnerabilities and the sliding mode control gives heartiness. Frameworks having less number of control contributions than the degrees of opportunity accessible are known as under actuated frameworks. Under actuated frameworks exist in a wide scope of ongoing applications, for example, aviation, mechanical autonomy, submerged vehicles, and adaptable frameworks.

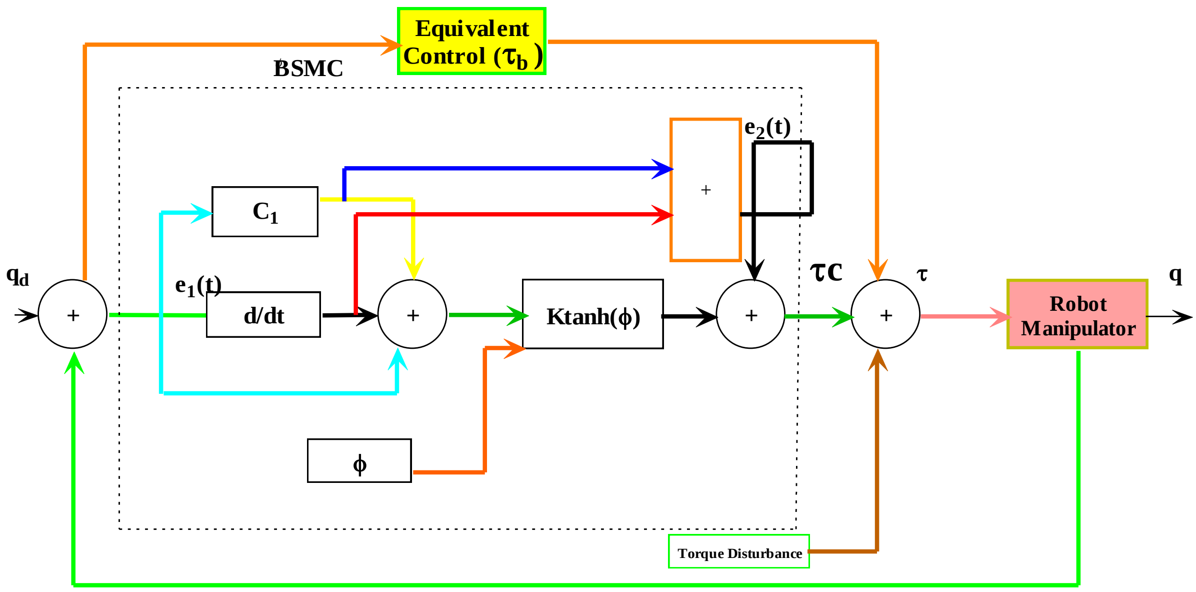

Fig 11 Block diagram of the back stepping SMC for robot manipulator

Figure 11 illustrates the frame work of the back stepping sliding mode control for robot manipulator. Where ϕ is boundary layer thickness of BSMC Controller and K sliding gain constant.

The robot manipulator design and stability of back stepping SMC is

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

$$\dot{x}_2 = \ddot{q} = D^{-1}(or)[\gamma - (c(q,\dot{q})\dot{q} + h(q) + F(q,\dot{q}) + \gamma d)] \qquad (10`$$

$$y = x_1 \qquad (11)$$

Where x_1 *and* x_2 are position and velocity vectors of the robot

The position tracing error is

$$e = q_d - q \qquad (12)$$

The stabilizing function is

Z

$$\alpha_1 = \lambda_1 e_1 \qquad (13)$$

Where α_1 *and* λ_1 are steady terms and positive constant

$$e_2 = \dot{e}_1 + \alpha_1$$

$$S = e_1 + e_2$$

$$\gamma_c = ksign(s)$$

$$\gamma_c = k\tanh(e_1 + e_2) \qquad (14)$$

$$S = e_1 + e_2 = e_1 + \dot{e}_1 + \alpha_1 = e_1 + \dot{e}_1 + \lambda_1 e_1 \qquad (15)$$

Table 7. Back stepping SMC TUNING parameters

S.no	lmd	L	k	error
1	10	100	10	0.001371
2	17	170	15	0.0009995
3	40	220	30	0.001418
4	60	400	40	0.001416
5	75	450	60	0.001011

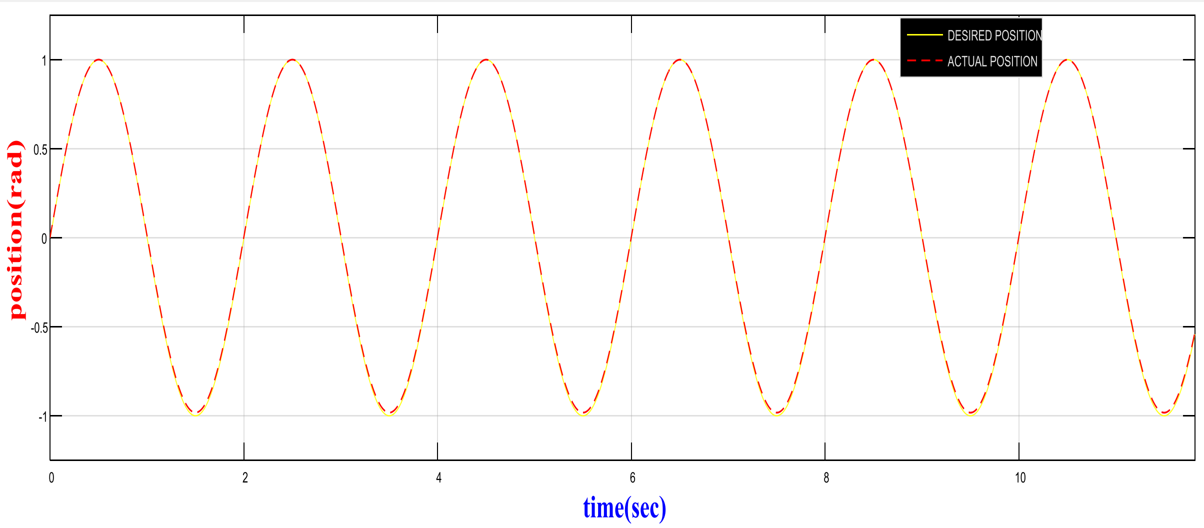

Fig 12 simulation response for back stepping smc

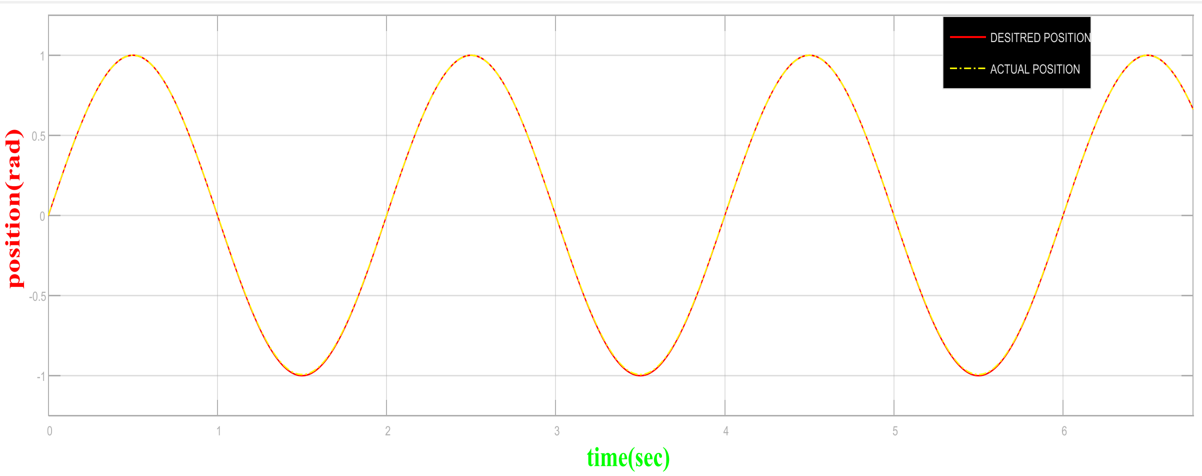

Fig 13 simulation response for back stepping smc

International Journal of Advances in Engineering and Management (IJAEM)
Volume 2, Issue 1, pp: 241-252 www.ijaem.net ISSN: 2395-5252

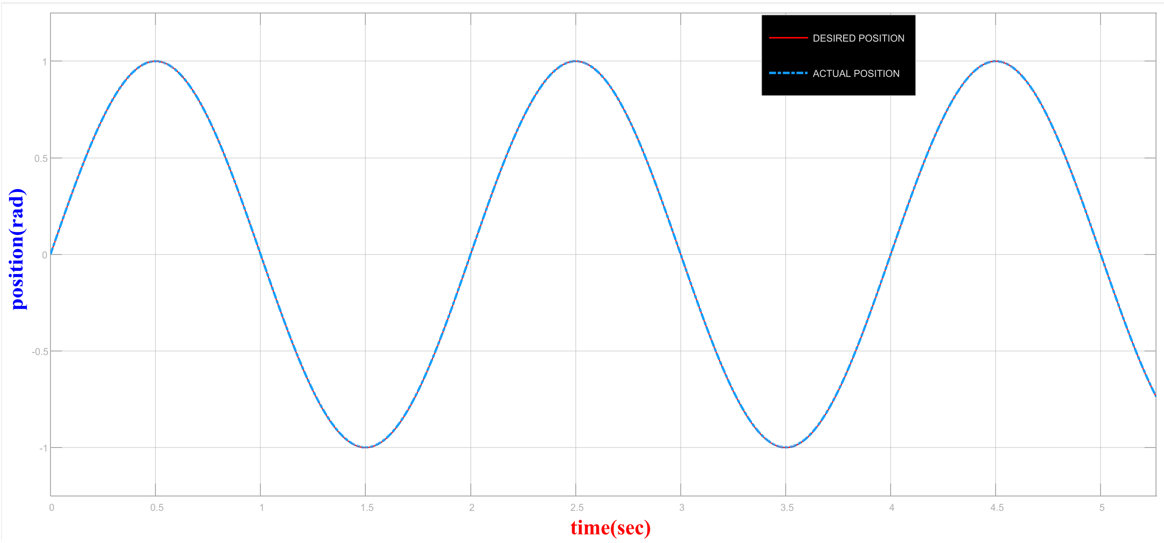

Fig 14 simulation response for back stepping smc

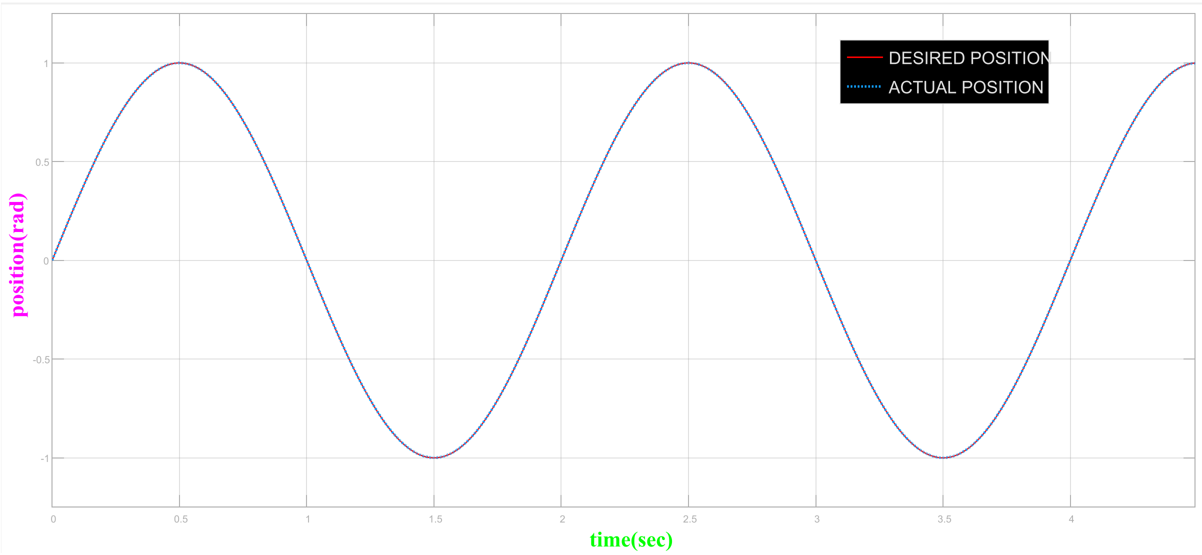

Fig 15 simulation response for back stepping smc

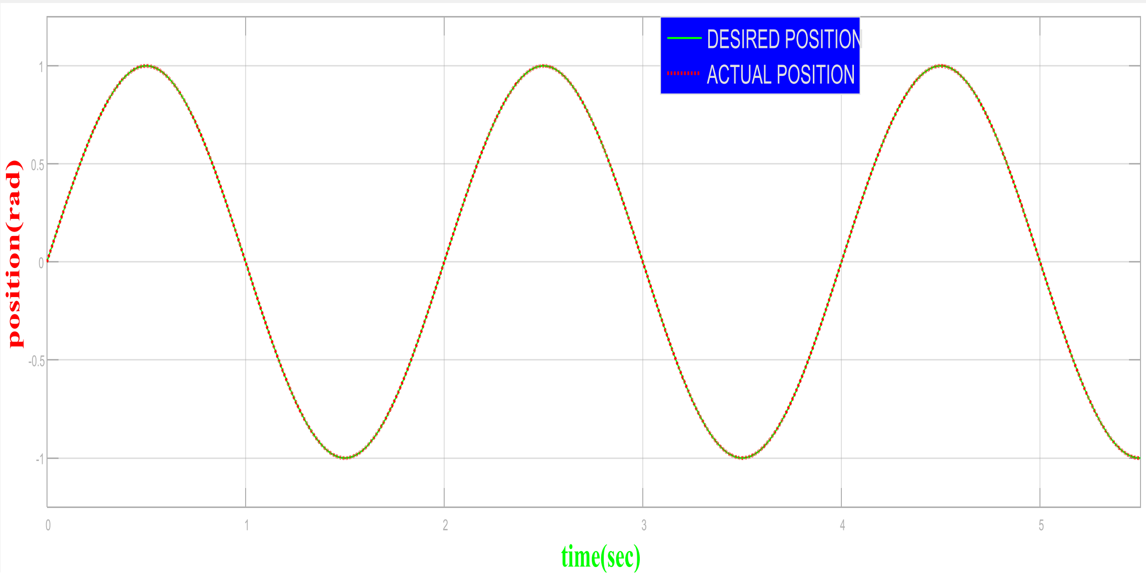

Fig 16 simulation response for back stepping smc

Figure 12 to figure 16 shows the various controllers i.e., SMC and BSMC. It is observed that compared to SMC, the BSMC provides better trajectory performance. The disturbance rejection is good with BSMC than SMC.

II. CONCLUSION

Control building for human-robot co-action in-network circumstances has been presented. The particular control circles, communitarian act ones, have been poor down and mirrored for the example of RH-2. The direct control structure for human-robot co-task in helpful has been shown. The particular SMC controllers have been separating and leg repeating for a humanoid robot. The position quality has been practiced by using the model of the single changed pendulum and controlling the robot's lower leg. Further research will focus on building up the nonlinearity and the clever based controllers for the leg model.

The BSMC controller is equipped for working in non-straight for control of the robot leg model with various attributes. It has been shown that the BSMC controller can effectively be created, which can give execution very near the assessed controller and much better than the traditional SMC controller and BSMC controller under concurrent torque unsettling influence of any irregular extents.

REFERENCES

[1]. G. S. Sreehari, M. Vijay, D. S. Sumanth and G. P. Kumar, "Wearable Exoskeleton Assisted Rehabilitation in Multiple Sclerosis by Control of Sliding Mode Technique," *2019 2nd International Conference on Intelligent Computing, Instrumentation and Control Technologies (ICICICT)*, Kannur,Kerala, India, 2019, pp. 1042-1048, doi: 10.1109/ICICICT46008.2019.8993349.

[2]. R.P Kumar, J.W. Yoon and G.S. Kim, “Simple dynamic walking model with Toed feet”, Proceedings of IEEE RAS International conference on a humanoid robot, Korea, 2008, PP.245-250.

[3]. C.A Monje, P. Pierro and C. Balaguer. “A new approach on human-robot collaboration with humanoid robot RH-2”, Robotica, 2011, Volume 29, pp.949-950, DOI: 017/s026357471100018X.

[4]. S. A Green, M. Billing Hurst, X. Chen and J.G. Chase, “Human-robot collaboration a literature review on augmented reality approach in design”, Int. J, Adv. Robot. Systems, Volume 5, no.1, 2088, pp. 1-18.

[5]. S. Kajita, T. Nagasaki, K. Yokoi, K. Kaneko and K. Tanie, “Running Pattern Generation for a Humanoid Robot”, Proceedings of IEEE International Conference on Robotics and Automation, EEUU, Washington DC, (2002) pp. 2755-2761.

[6]. G. S. Sreehari, M. Vijay and A.V. Pavan Kumar “Wearable Exoskeleton Assisted Rehabilitation in Multiple Sclerosis by Using Conventional Control Methods” 3rd international Conference on Computing

Methodologies and Communication (ICCMC 2019), IEEE, 2019.

[7]. T. Sugahara and Y. Nakamura," Variable Impudent Inverted Pendulum Model Control for a Seamless Contact Phase Transition on Humanoid Robot", Proceedings of IEEE International Conference on Humanoid Robots (Humanoids 2003), Germany (2003).

[8]. S. Kajita and K. Tani, "Simplest of Dynamic Biped Locomotion on Rugged Terrain", Proceedings of IEEE International Conference on Robotics and Automation (ICRA) (1991) pp. 1405-1411.

[9]. T. Kimura, H. Leung, S. Kudoh and J. Kuffner," A Feedback Controller for Biped Humanoids that Can Counteract Large Perturbations During Gait", Proceedings of IEEE International Conference on Robotics and Automation (ICRA), Barcelona, Spain, (2005) pp.2001-2007.

[10]. Y. Yamamoto, H. Eda and X. Yun, "Coordinated Task Execution of a Human and a Mobile Manipulator," Proceedings of IEEE International Conference on Robotics and Automation, Vol. 2 (1996), PP. 1006-1011.

[11]. T. Komura, A. Nagano, H. Leung and Y. Shinagawa," Simulating Pathological Gait using the enhanced Linear inverted pendulum model", IEEE Trans.Biomed.Eng.52(90), 1502-1513 (2005)

[12]. Roberta Alo, Francesco Bottiglione and Giacomo," Kinematic Energy Recovery in Human Joints: The Flywheel-Infinitely Variable Transmission Actuator", Springer International Publishing AG 2017 J. Gonzalez-Vargas et al. (eds.), Wearable Robotics: Challenges and Trends, Bio system & Bio robotics 16, DOI 10.1007/978-3-319-46532-6_7.

[13]. P. Pierro, C. A. Monje and C. Balaguer, "Modelling and Control of the Humanoid Robot RH-1 for Collaborative Tasks," Proceedings of IEEE RAS/RSJ Conference on Humanoid Robots, Dajeon, Korea (2008) PP. 125-131.

[14]. J. Y. Kim, I. W. Park and J. H. Oh, "Walking Control algorithm of biped humanoid robot on the uneven and inclined floor" J. Intell. Robot. Syst. 48(4), 457-484 (2007).

[15]. B. Stephens and C. Atkeson, "dynamic balance force control for compliant humanoid robots," in Intelligent Robots and Systems (IROS), 2010 IEEE/RSJ International Conference on, Oct 2010, PP. 1248-1255.

[16]. G. S. Sreehari, M. Vijay and A. V. P. Kumar, "Wearable Exoskeleton Assisted Rehabilitation in Multiple Sclerosis by Using Conventional Control Methods," *2019 3rd International Conference on Computing Methodologies and Communication (ICCMC)*, Erode, India, 2019, pp. 49-53, doi: 10.1109/ICCMC.2019.8819682.

[17]. Khademi, G., Mohammadi, H., Hardin, E.C, Simon, D., 2015, "Evolutionary optimization of user intent recognition for trans femoral amputees", submitted to Biomedical Circuits and Systems Conference, Atlanta, Georgia, USA.

[18]. Richter, H., Simon, D., Smith, w, Samorezov, S., 2015., "Dynamic modelling, parameter estimation and control of a leg prosthesis test robot", Applied Mathematical Modelling, vol. 39, no. 12, pp. 559-573.

[19]. Mohammadi, H., Richter, H., 2015, "Robust Tracking/Impedance Control: Application to prosthetics," American Control Conference, Chicago, Illinois.

[20]. Gregg, R.D., Sensinger, J.w., 2014, "Towards biomimetic virtual constraint control of a powered prosthetic leg", IEEE Transactions on Control Systems Technology, vol. 22, no. 1, pp. 246-254.

[21]. Richter, H., Simon, D., and Van den Borgert, A., 2014., Semi-active virtual control method of robots with regenerative energy-storing joints", 19th, the International Federation of Automatic Control World Congress, Cape Town, South Africa.

[22]. Hoover, C.D., Fulk, G.D., Fite, K.B., 2013, "Stair ascent with a powered trans femoral prosthesis under direct myoelectric control," IEEE-ASME Transactions on Mechatronics, vol. 18, no. 3, pp. 1191-1200

[23]. G. S. Sreehari, M. Vijay, B. R. Kushal and G. Praveen, "Wearable Exoskeleton Assisted Rehabilitation in Multiple Sclerosis by Using an Intelligent Control Method," *2019 2nd International Conference on Intelligent Computing, Instrumentation and Control Technologies (ICICICT)*, Kannur,Kerala, India, 2019, pp. 975-981, doi: 10.1109/ICICICT46008.2019.8993355.

International Journal of Advances in Engineering and Management
ISSN: 2395-5252

IJAEM

Volume: 02 Issue: 01 DOI: 10.35629/5252

www.ijaem.net
Email id: ijaem.paper@gmail.com