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HNN Based Controller Optimization of Flexible Single-Link Manipulator

Namrata Lade[1], Prof.Om prakash[2]
[1](Department of Electronics, Atharva College of Engineering, Malad-West, Mumbai-400095,
[2](Department of Electronics and Telecommunication,

Abstract: *As we know the manipulator performs the important role in nanotechnology and biotechnology. The flexible link manipulators are important as the robots are used in industrial purpose in which heavy task is performed. This paper presents a review on various studies of flexible link manipulators. We have studied much previous research on flexible link controller. In their research we have found some issue like, energy consumption, error, hub angle problem etc. In this paper we will go through various papers and from this we can find different issues related manipulators.*
Key words: *FTSMC,Fuzzy Logic,Control Optimization,Trajectory Tracking*

I. Introduction

Robotic manipulators are exceedingly requested to work in dangerous, daily practice, difficult jobs rather than human so as to accomplish precise, quicker, and efficient tasks. Traditional solution for maintain a strategic distance from the end effectors vibration and accomplishing great position exactness is utilizing overwhelming material and massive plans to accomplish a high solidness for automated controllers. The powerful utilization, low speed, risk, and less profitability are the weaknesses of the substantial inflexible controllers utilized of the most existing robotic manipulators [29].

So as to build modern robotic manipulators to fulfill the necessities of modern applications, it is critical to guarantee by diminishing the heaviness of the link manipulators and use flexible materials to fulfill the uncommon needs of businesses. Huge control issues show up in flexible link manipulators, for example, vibration, and static deflection from designing errors and external effects. These elements can diminish the end effector accuracy, increment settling time, and entangle the controller configuration plot. As of now, flexible link manipulators have been structured and have the accompanying points of interest: (I) more prominent the proportion of payload load to robot weight, (ii) utilization of less incredible actuators which decreases the vitality utilization, (iii) less expensive development, (iv) quicker movement, (v) safe task[27].

The demonstrating and controlling the vibrational phenol-mena portraying flexible systems enable engineers to structure and fabricate lighter robot manipulators which would offer the requested points of interest [28].

Different fields ask for flexible manipulators, yet controlling and suppression the vibration of the flexible link manipulators are still viewed as tremendous difficulties [29].The issue of controlling automated systems which are joined with flexible link have been explored by control architects and roboticists for about 10 years [32]. As announced in [29], the control difficulty is brought about by the way that since the manipulator is a distributed framework; an extensive number of flexible modes are required to precisely show its conduct. Further, complexities emerge due to the exceedingly nonlinear nature of the system. We will study various papers of flexible link manipulator in next section.

II. Literature review

In [1], they proposed reinforcement learning control of a single-link flexible manipulator and endeavor to smother the vibration because of its lightweight structure and flexibility. The expected mode strategy and the Lagrange's condition are received in modelling to upgrade the fulfillment of exactness. The spiral capacity neural systems (NNs) are utilized in the designed control algorithm, on-screen character NN for creating a strategy and commentator NN for assessing the expense to-go.

In [2], they had built up the dynamic model of an flexible robotic manipulator by utilizing the assumed mode strategy. In this manner, base on the discretized dynamic model, fuzzy control has been concentrated to accomplish the control goals. Going for guaranteeing strength thoroughly, uniform extreme boundedness (UUB) of the closed-loop framework has been accomplished by means of the Lyapunovs stability. Furthermore, the condition of the framework has been demonstrated to merge to zero with a little neighborhood by fittingly picking structure parameters.

In [3], they had shown two diverse control methodologies for a system with a solitary adaptable connection. It incorporates demonstrating and controlling a pivoting Quanser flexible beam. Utilizing Lagrange conditions, they had acquired a straight unique model communicated by common differential conditions. A Linear Quadratic Regulator and a State Feedback controller utilizing the deflection feedback measured by a strain gauge by a strain measure, is proposed to limit vibrations because of the adaptability of the connection. The proposed controllers are executed and reproduced, and exploratory outcomes demonstrated that dependent on the tip diversion criticism, dynamic vibration of the flexible link is significantly minimized.

In [4], presents the design of active disturbance rejection control (ADRC) technique to position control of asingle link flexible joint robot manipulator. Two plans of ADRC are introduced, Linear Active Disturbance Rejection Controller (LADRC) and Nonlinear Active Disturbance Rejection Controller (NADRC). An comparison study in terms of transient performances, robustness qualities and unsettling influence dismissal abilities has been made dependent on LADRC and NADRC. The strength of the two controllers is assessed by estimating the measure of deviation in framework execution because of vulnerability in framework parameters, One issue with NADRC and LADRC is they incorporate different parameters and except if they are legitimately tuned, they adversy affected the estimation procedure and thus, on the system performance. The molecule swarm technique (PSO) has been chosen as an ideal tuner to improve the estimation procedure and along these lines, to upgrade the system performance.

In [5], researches the singular perturbation (SP) hypothesis based composite learning control of an a flexible-link manipulator utilizing disturbance observer (DOB) and neural systems (NNs). For the elements, the system states are isolated into moderate and quick factors as far as time scale. For the multi-output- multi-input slow dynamics, the clever control is planned where NNs are utilized for framework vulnerability guess and the DOB is utilized for compound aggravation estimation.

In [6], tended to trajectory tracking issue, a quick nonsingular terminal sliding mode control was proposed, which can improve the intermingling time contrasted and conventional terminal sliding mode control. The evidence of system stability is given by the Lyapunov hypothesis.

In [7], implement an controller optimization system for single-link flexible manipulator. They had used different methods like discretised using the finite difference and Lagrange equation. The genetic algorithm (GA) is utilized to upgrade parameter of PID controller. They had thought about both flexible–link manipulators. They have done vibration reduction utilizing PID and ILC input control technique which depends on genetic algorithm.

In [8], developed an fuzzy logic control system with n optimization algorithm. This control system is develop for reference tracking control. To optimize tuning parameter of fuzzy logic control modified invasive weed optimization (MIWO) algorithm is used.

In [9], developed a system for hub motion and end point vibration suppression of two link flexible manipulator. This framework is planned utilizing multi-layer perceptron neural system structures dependent on Nonlinear Autoregressive Exogenous (NARX) demonstrate. The half breed controller is joined with advancement calculation. The calculation PSO and ABC are utilized. These calculations are utilized to discover the parameters enhancement of PID controller. This framework is used to evaluate vibration suppression and tracking capabilities.

In [10], presents 2 strategies for the control of two link- robotic manipulator with different load, the main strategy depends on Proportional-Integral-Derivative controller, and the second technique artificial Neural Network by PID controller for control of link- robotic manipulator systems.

In [11], proposed the sliding mode control with NN and DOB for compound estimation. The composite learning control plan can enormously improve the tracking execution results affirms the structure theory that the composite learning can learning satisfy the estimation undertaking.

In [12], adaptive controller of nonlinear PID-based simple neural systems is created for the point to point and orientation-tracking control of a two link rigid robot manipulator. For each situation, the maximum load conveying limit of robot manipulator subject to precision and actuators imperatives is acquired. In correlation with traditional PID strategy, the utilization of neural system controller can expand most extreme load conveying limit of robot controllers. A sublime blend of a neural system and ordinary PID controller, which has ground-breaking ability of consistently online learning, adjustment and handling nonlinearity, presents to us the novel nonlinear PID-based simple neural system controller.

In [13], depicts a hybrid approach way to deal with the issue of controlling flexible link manipulators in the dynamic period of the trajectory. An adaptable beam/arm is an engaging alternative for military and civil applications, for example, space-based robot manipulators. Be that as it may, flexibility carries with it undesirable extreme chattering and oscillations which may even prompt an unsteady framework. To fathom these difficulties, a novel control design plot is exhibited.

In [14], new structure of PID type fluffy rationale controller is proposed in which Fuzzy PI controller and conventional PD controller is associated in parallel. The increases of the proposed controller are determined by Gradient descent optimization method. Illustrative precedents are considered to approve the execution of their structure.

In [15],talked about two sorts of controllers, the State-Feedback controller, and the Linear-Quadratic controller (LQR). While the last is acquired by settling the Riccati condition, the state-criticism comprises on shafts position. A State-Feedback controller and a Linear Quadratic Regulator utilizing the tip avoidance input estimated by a strain measure, is proposed to limit vibrations because of the flexibility of the connection.

In [16], proposed and system for trajectory of manipulators. They had used n L1-ILC framework for trajectory tracking. They had model L1 adaptive feedback with iterative learning control (ILC) framework to improve trajectory tracking of a system subject to changing disturbances and unknown. Based on experience from previous executions ILC improves the performance.

In [17], had proposed open loop optimal control method as an approach for trajectory optimization of flexible mobile manipulator for a given two end point task in point-to-point motion. The dynamic equations are derived using combined Euler Lagrange formulation and also assumed modes method. An indirect method via establishing the Hamiltonian function and deriving the optimality condition from Pontryagin's minimum principle is employed to solve the optimal solution. The obtained equations provide a two point boundary value problem which is solved by various techniques. By changing the penalty matrices values which able the designer to choose the best trajectory, obtaining various optimal trajectories methods with different characteristics is the main advantage of this system.

In [18], presented sliding mode controller for flexible link manipulator. They had presented output feedback control for positioning a tip of flexible link manipulator using sliding modes. For estimation of system states the sliding mode observer is designed. It gives zero error due to sliding mode. For positioning a tip of FLM the SMC with SMO is designed.

In [19], proposed two types of sliding mode control first is normal sliding mode control and second is Quasi sliding mode control are used in controlling single link rotational base flexible manipulator for three different payloads. For chattering elimination Quasi-SMC is used which is present in the case of SMC. As, sliding mode control is insensitive to parameter disturbances and uncertainties within some bounds, it helps in tracking the controlling the dynamics and desired trajectories. Tip hub angle and deflection are controlled using SMC with payload variation of 0.0Kg, 0.1Kg, and 0.5Kg.

In [20], system for tracking control of the rigid link and the flexible link system adaptive networks based fuzzy logic controllers are used. The testing data and training of adaptive networks based fuzzy logic controllers are obtained from the PD control of the manipulator system. The performances of adaptive networks based fuzzy logic controllers are tested for different type and different number of membership functions.

In [21], presented LabVIEW based Fuzzy PI controller for angular position control of adaptable connection controller. An a flexible link manipulator has various favorable circumstances over an inflexible link, for example, light weight, rapid with low dormancy, vast work space and devour less vitality relatively.

In [22], introduces the dynamic model of a planar manipulator with two flexible links and particle filtering algorithm. Then the Particle filtering is applied to estimate the state vector of manipulator model when joints' angles and end-point' position are observations. Under the same non-Gaussian simulation environment, the comparisons between particle filtering and extended Kalman filtering about estimation accuracy of the end-point's position indicate that the former have the better performance.

In [23], performed dynamics of 3-DOF spatial parallel manipulators with flexible links. They had proposed model of spatial flexible beam elementand the dynamic equations of elements and a branch of the parallel manipulator was derived. Using the kinematic and dynamic constraint equations of the parallel manipulator, the overall system dynamic equations of the parallel manipulator was obtained by assembling the dynamic equations of branches. And also, the dynamic response of the 3-RRS parallel mechanism with flexible links was analyzed through numerical simulation.

In [24], presented the elastic variable of space robot flexible arms with the flexible arm link end deformation and deformation angle. This system overcome the difficulty which may be brought by infinite dimensional vibration variable of flexible arm in modeling system kinematics. The kinematic condition of adaptable arm space robot which incorporates flexible variable is set up as summed up Jacobian framework.

In [25], proposed a design methodology of self reconfigurable kinematics and control scheme for modular and reconfigurable robots. A particular controller has been proposed to meet the prerequisite of assignment adjustment in adaptable requirements for modern and administration robot zone. For self-reconfiguration of structured particular kinematic, controllers and dynamic settings are extricated from provided modules and get together data and related codes are consequently created including controller. Along these lines a client can without much of a stretch form and utilize a secluded robot without expert information for required errands.

In [26], framework tends to both joint and connection adaptabilities in the meantime. And furthermore expected mode demonstrate is given to set up the adaptable connection kinematics. In the expected mode demonstrate, every one of the parameters are considered as elements of time and time-dependent recurrence condition is given. At long last, a RRP controller is embarked to demonstrate the exact kinematics model.

Sr No	Title	Authors	Algorithm/Methods	Resullts
1	PID-based Control of a Single-Link Flexible Manipulator in Vertical Motion with Genetic Optimisation [7]	B.A. Md Zain, M. O. Tokhi, and S.F. Toha	Genetic Algorithm	The control scheme had shown to perform well in reducing the vibration at the end-point of the manipulation.
2	Fuzzy logic based controller for a single-link flexible manipulator using modified invasive weed optimization [8]	Hyreil A Kasdirin, M. Assemgul and M. O. Tokhi	fuzzy logic control, IWO algorithm, MIWO algorithm	Better accuracy and improve the local search ability
3	Implementation of PID based controller tuned by Evolutionary Algorithm for Double Link Flexible Robotic Manipulator[9]	Annisa J. I.Z Mat Darus and M.O Tokhi	Neural Network, Particle Swarm Optimization, Artificial Bees Algoritmn	It is revealed that PSO controllers offer the best outcomes compared to ABC.
4	High-Precision Trajectory Tracking in Changing Environments Through L1 Adaptive Feedback and Iterative Learning [16]	Karime Pereida, Rikky R. P. R. Duivenvoorden, and Angela P. Schoellig	Iterative learning control	Their system proved that the proposed framework is stable and achieves learning convergence.
5	Trajectory Optimization of Flexible Mobile Manipulators Using Open-Loop Optimal Control Method [17]	M.H. Korayem and H. Rahimi Nohooji	Euler–Lagrange formulation andassumed modes method	Obtainined various optimal trajectories with different characteristics.
6	Output feedback control of flexible link manipulator using sliding modes [18]	Shailaja Kurode and Prashant Dixit	Sliding Mode Control	This paper presents output feedback control for positioning a tip of flexible link manipulator.
7	Control of Rotational Base Single Link Flexible Manipulator using Different SMC Techniques for Variable payloads[19]	Surajit Suklabaidya, Kshetrimayum Lochan and B. K. Roy	Sliding Mode Control	Tip deflection and hub angle are controlled using SMC
8	Adaptive Network Based Fuzzy Logic Control of a Rigid – Flexible Robot Manipulator [20]	Umit Onen, Mustafa Tinkir, Mete Kalyoncu and Fatih Mehmet Botsali	Fuzzy logic control	Better position control performances
9	LabVIEW based Fuzzy PI for Flexible Link Manipulator [21]	Yograj Sharma and Jyoti Ohri	Fuzzy logic control	Their proposed controller gives better performance in terms of both transient and steady state response.
10	Kinematics of Reconfigurable Flexible- Manipulator Using a Local Product-of-Exponentials Formula [26]	Ying Li, Mingchao Zhu and Yuanchun Li	Local Product-of-Exponentials Formula	An explicit, complete and accurate framework has been described to automatically

From above literature review we have found various problems related to manipulators, the main problem is that flexibility of manipulators, vibration, hub angle, more energy consumption. We can overcome this problem by optimizing the controllers in term of their performance.

We are going to implement a Hybrid Neural Network (HNN) based optimization to optimize the controllers. Here we will optimize two controllers first, Sliding Mode Controller (SMC) and Fuzzy logic Controller by which problem of energy consumption, error, vibration suppression and trajectory tracking will be eliminated. We are also improving the performance of SMC by implementing the Fast Terminal Sliding Mode Controller. This simulation can be done by using Matlab Simulink.

III. Proposed Methodology

There are two controller are used in this system that are sliding mode controller and Fuzzy logic controller. To control the manipulators these controllers are used. In previous system energy consumption due to multiple links, error, vibration suppression is more. To reduce this disadvantages it need to optimize the controllers. To optimize the controller we are using hybrid Neural Networks (HNN). Here our main contribution is the fast terminal sliding mode controller. Following fig shows system architecture.

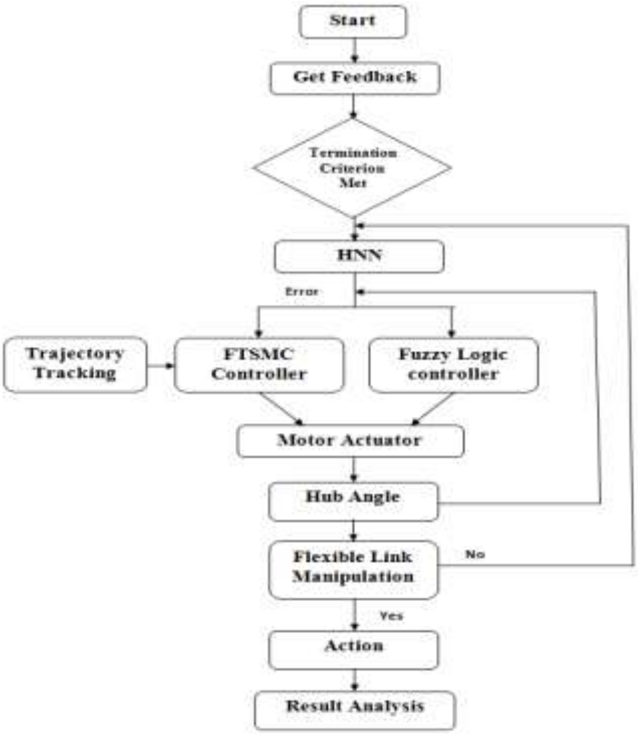

Fig. 1: HNN Based Controller Optimization of Flexible Single-Link Manipulator

IV. Conclusion

In the field of robotic the main part is manipulator. Manipulators are used in heavy duty work which is repeated. It is need to have flexibility in manipulators. More energy is consumed by manipulators due to more batteries are used in flexible link manipulators. Due to this it also produce more vibrations, noise, and tracking etc. These all problems are studied from this paper. It need to solve this problem by optimizing the controller. This review has briefly discussed the modeling flexible link manipulators. Furthermore, optimization of controller is the main contribution of this literature revirew.

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