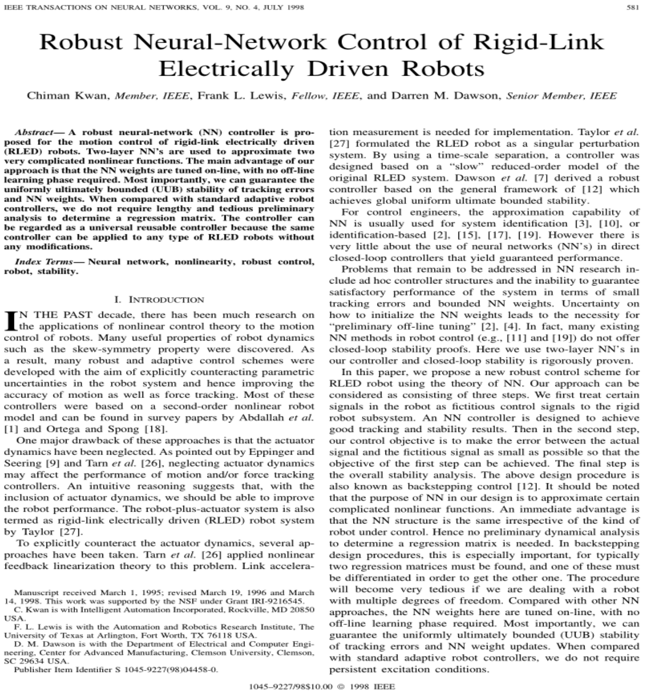
Control Of Uncertain Dynamic Systems: A Collection Of Papers Presented At The International Workshop



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Robust Neural-Network Control of Rigid-Link Electrically Driven Robots

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***Abstract*— A robust neural-network (NN) controller is proposed for the motion control of rigid-link electrically driven (RLED) robots. Two-layer NN's are used to approximate two very complicated nonlinear functions. The main advantage of our approach is that the NN weights are tuned on-line, with no off-line learning phase required. Most importantly, we can guarantee the uniformly ultimately bounded (UUB) stability of tracking errors and NN weights. When compared with standard adaptive robot controllers, we do not require lengthy and tedious preliminary analysis to determine a regression matrix. The controller can be regarded as a universal reusable controller because the same controller can be applied to any type of RLED robots without any modifications.**

***Index Terms*— Neural network, nonlinearity, robust control, robot, stability.**

I. Introduction

IN THE PAST decade, there has been much research on the applications of nonlinear control theory to the motion control of robots. Many useful properties of robot dynamics such as the skew-symmetry property were discovered. As a result, many robust and adaptive control schemes were developed with the aim of explicitly counteracting parametric uncertainties in the robot system and hence improving the accuracy of motion as well as force tracking. Most of these controllers were based on a second-order nonlinear robot model and can be found in survey papers by Abdallah *et al.* [1] and Ortega and Spong [18].

One major drawback of these approaches is that the actuator dynamics have been neglected. As pointed out by Eppinger and Seering [9] and Tarn *et al.* [26], neglecting actuator dynamics may affect the performance of motion and/or force tracking controllers. An intuitive reasoning suggests that, with the inclusion of actuator dynamics, we should be able to improve the robot performance. The robot-plus-actuator system is also termed as rigid-link electrically driven (RLED) robot system by Taylor [27].

To explicitly counteract the actuator dynamics, several approaches have been taken. Tarn *et al.* [26] applied nonlinear feedback linearization theory to this problem. Link acceleration measurement is needed for implementation. Taylor *et al.* [27] formulated the RLED robot as a singular perturbation system. By using a time-scale separation, a controller was designed based on a "slow" reduced-order model of the original RLED system. Dawson *et al.* [7] derived a robust controller based on the general framework of [12] which achieves global uniform ultimate bounded stability.

For control engineers, the approximation capability of NN is usually used for system identification [3], [10], or identification-based [2], [15], [17], [19]. However there is very little about the use of neural networks (NN's) in direct closed-loop controllers that yield guaranteed performance.

Problems that remain to be addressed in NN research include ad hoc controller structures and the inability to guarantee satisfactory performance of the system in terms of small tracking errors and bounded NN weights. Uncertainty on how to initialize the NN weights leads to the necessity for "preliminary off-line tuning" [2], [4]. In fact, many existing NN methods in robot control (e.g., [11] and [19]) do not offer closed-loop stability proofs. Here we use two-layer NN's in our controller and closed-loop stability is rigorously proven.

In this paper, we propose a new robust control scheme for RLED robot using the theory of NN. Our approach can be considered as consisting of three steps. We first treat certain signals in the robot as fictitious control signals to the rigid robot subsystem. An NN controller is designed to achieve good tracking and stability results. Then in the second step, our control objective is to make the error between the actual signal and the fictitious signal as small as possible so that the objective of the first step can be achieved. The final step is the overall stability analysis. The above design procedure is also known as backstepping control [12]. It should be noted that the purpose of NN in our design is to approximate certain complicated nonlinear functions. An immediate advantage is that the NN structure is the same irrespective of the kind of robot under control. Hence no preliminary dynamical analysis to determine a regression matrix is needed. In backstepping design procedures, this is especially important, for typically two regression matrices must be found, and one of these must be differentiated in order to get the other one. The procedure will become very tedious if we are dealing with a robot with multiple degrees of freedom. Compared with other NN approaches, the NN weights here are tuned on-line, with no off-line learning phase required. Most importantly, we can guarantee the uniformly ultimately bounded (UUB) stability of tracking errors and NN weight updates. When compared with standard adaptive robot controllers, we do not require persistent excitation conditions.

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Control of uncertain dynamic systems: a collection of papers presented at the International Workshop on Robust Control, San Antonio, Texas, March Control of Uncertain Dynamic Systems - CRC Press Book. This book is a collection of 34 papers presented by leading researchers at the International Workshop on Robust Control held in San Antonio, Texas in March The common.INTERNATIONAL JOURNAL OF ROBUST AND NONLINEAR CONTROL, VOL. 5, () control theory. This book is a collection of. 34 papers presented at one such workshop which was held in San Antonio, Texas, in March book is a collection of 34 papers presented by leading researchers at the International Workshop on Robust Control held in San Antonio, Texas in March UNCERTAIN DYNAMIC SYSTEMS A collection of papers presented at the International Workshop on Robust Control, San Antonio, Texas, March Edited.[14] H. Kimura, "LQG as a design theory," in Mathematical System Theory: The [15] H. Kimura, "Generalized chain-scattering approach to H control problems," in Control of Uncertain Dynamic Systems: A Collection of Papers Presented at the International Workshop on Robust Control, San Antonio, Texas, March , .Systems Control Group, Texas A&M University . on Robust Stability of Interval Dynamic Systems November , San Organizer of the International Workshop on Robust Control held in March . Professor Antonio Vicino L.H. Keel and romagna-booking.comcharyya, Control of Uncertain Dynamic Systems.Control Group, Texas A&M University Director, Systems and Control Institute, Texas Engineering . on Robust Stability of Interval Dynamic Systems November , San of the International Workshop on Robust Control held in March .. Uncertain Dynamic Systems, CRC press, October An international workshop dealing with all aspects of robust control was successfully organized by S. P. Bhattacharyya and L. H. Keel in San Antonio, Texas, USA in March a collection of papers presented at the International Workshop on Robust Control Computation of Value Sets of Uncertain Transfer Functions.?10?24? This book is a collection of 34 papers presented by leading researchers at the on Robust Control held in San Antonio, Texas in March Control; Robust Control; Flight Dynamics and Control; Optimization Methods; Applied IASTED International Conference on Intelligent System and Control Session Best Paper Presentation Awards, American Control Conference, , , 32nd IEEE Conference on Decision and Control, San Antonio, Texas.(J)1 Davison, E.J., A method for simplifying linear dynamic systems, IEEE Trans on 1This paper has been identified as being one of the most cited items in its field controls, Hawaii International Conference on System Sciences, January uncertainties, Robust Control Workshop, March , , San Antonio, TX.is a collection of 34 papers presented by leading researchers at the International Workshop on Robust Control held in San Antonio, Texas in March International Journal of Robust and Nonlinear Control. . Systems for the Management of Vehicle Dynamics" (). Ilmenau, German, March 20, ? Associate Editor (Contributed Papers) for IEEE Conference on Control Conference on Decision and Control CDC'93", San Antonio, Texas, Nyquist Lectureship, ASME, Dynamic Systems and Control

Division Hybrid Systems: Computation and Control, First International Workshop, Distinguished Lecture Series in Computation for Design and Optimization .. , , also Proc. of the IEEE Conf. on Decision and Control, San Antonio.An international workshop dealing with all aspects of robust control was successfully organized by S. P. Bhattacharyya and L. H. Keel in San Antonio, Texas, USA in March a collection of papers presented at the International Workshop on Robust Lyapunov Functions for Uncertain Systems.