Identification and control of class of non-linear systems with non-symmetric deadzone using recurrent neural networks

José Humberto Pérez-Cruz1,3, Isaac Chairez2, Jose de Jesús Rubio3, Jaime Pacheco3

1Centro Universitario de Ciencias Exactas e Ingenierías, Universidad de Guadalajara Blvd., Marcelino García Barragán No. 1421, C.P. 44430, Guadalajara, Jalisco, Mexico
2Departamento de Bioelectrónica, UPBI-IPN, Av. Acueducto s/n, Barrio La Laguna, Col. Ticomán, C.P. 07340, Mexico City, D.F, Mexico
3Sección de Estudios de Posgrado e Investigación, -ESIME UA-IPN, Av. de las Granjas no. 882, Col. Santa Catarina, C.P. 02250, Mexico City, D.F, Mexico
E-mail: jose_humberto_perez@yahoo.com

Abstract: In this study, a neuro-controller with adaptive deadzone compensation for a class of unknown SISO non-linear systems in a Brunovsky form with uncertain deadzone input is presented. Based on a proper smooth parameterisation of the deadzone, the unknown dynamics is identified by using a continuous time recurrent neural network whose weights are adjusted on-line by stable differential learning laws. On the basis of this neural model so obtained, a feedback linearisation controller is developed in order to follow a bounded reference trajectory specified. By means of Lyapunov analysis, the boundedness of all the closed-loop signals as well as the weights and deadzone parameter estimations is rigorously proven. Besides, the exponential convergence of the actual tracking error to a bounded zone is guaranteed. The effectiveness of this scheme is illustrated by a numerical simulation.

1 Introduction

The deadzone is a non-smooth non-linearity which can provoke a loss of sensitivity in a control system. Specifically, when the input of a system subjected to this non-linearity stays in the so-called dead band, the output of this system is zero although its input is different from zero. This phenomenon is common in many practical systems such as DC servo motors, hydraulic and pneumatic servo valves, electronic circuits and so on [1–8]. If the presence of the deadzone is not considered explicitly during the design process, the performance of the control system could be degraded because of an increase of the steady-state error, the appearance of limit cycles or inclusive instability [9–14].

Basically, in the technical literature, two approaches have been proposed in order to overcome the deleterious effect of the deadzone: (a) by calculating the inverse of this non-smooth non-linearity, and (b) by modelling the deadzone as a combination of a linear term and a disturbance-like term. The second approach was originally presented in [15]. In that work, based on the aforementioned model, an adaptive robust controller was applied to a class of SISO systems with unknown dynamics formed by known non-linear functions and linearly parameterised unknown constants and with unknown constant control gain. This class of systems can be represented as

\[ y^{(n)}(t) = \sum_{j=1}^{r} a_j Y_j(y(t), \dot{y}(t), \ldots, y^{(n-1)}(t)) + bu(t) + \xi(t) \]

where the scalar \( y(t) \) is the output of the system, \( Y_j : \mathbb{R}^n \rightarrow \mathbb{R} \) are known continuous linear or non-linear functions, \( \xi(t) \) is a bounded disturbance, \( a_j, i = 1, \ldots, r \) and control gain \( b \) are unknown constants and \( u(t) \in \mathbb{R} \) is the output of the deadzone. The main drawback of [15] is the assumption of a deadzone with strictly symmetric slopes. This constraint was overcome in [16] by a new parameterisation of the deadzone, and by developing an adaptive control strategy applied to the same class of systems as in [15]. Finally, in [17, 18], the results from [16] could be generalised to a wider class of systems. Certainly, the most common approach to handle deadzone presence is by calculating its inverse. However, this is not a simple operation because in many practical situations, both the parameters and the output of the deadzone are unknown. To deal with this problem, in a pioneer work [8], Tao and Kokotovic proposed to employ an adaptive inverse. This scheme was applied to linear systems in transfer function form. Cho and Bai [19] extended this work and achieved a perfect asymptotic adaptive cancellation of the