

MODEL REFERENCE ADAPTIVE CONTROL FOR MOBILE ROBOTS IN TRAJECTORY TRACKING USING RADIAL BASIS FUNCTION NEURAL NETWORKS

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Abstract— This paper propose an Model Reference Adaptive Control (MRAC) for mobile robots for which stability conditions and performance evaluation are given. The proposed control structure combines a feedback linearization model, based on a kinematics nominal model, and a direct neural network-based adaptive dynamics control.

The architecture of the dynamic control is based on radial basis functions neural networks (RBF-NN) to construct the MRAC controller. The parameters of the adaptive dynamic controller are adjusted according to a law derived using Lyapunov stability theory and the centers of the RBF are adapted using the supervised algorithm.

The resulting MRAC controller is efficient and robust in the sense that it succeeds to achieve a good tracking performance with a small computational effort. Stability result for the adaptive neuro-control system is given. It is proved that control errors are ultimately bounded as a function of the approximation error of the RBF-NN. Experimental results showing the practical feasibility and performance of the proposed approach to mobile robotics are given.

Keywords — system identification, adaptive neural nets, mobile robot control.

I. INTRODUCTION

Real-time trajectory control of a mobile robot is a very important issue in mobile robotics. Due to slippage, disturbances, noise, robot-base interaction and sensor errors, it is very difficulty to reduce the errors between the desired and real robot position. How to effectively control a mobile robot to precisely track a desired trajectory is still an open question in robotics.

Several studies have been published regarding the design of controllers to guide mobile robots during trajectory tracking. Most of the controllers designed so far are based only on the kinematics of the mobile robot, like the controllers presented in Carelli *et al.* (1999), in Wu *et al.* (1999) and in Kühne *et al.* (2005). To perform tasks requiring high speed movements and/or heavy load transportation, it is important to consider the robot dynamics, besides its kinematics. No matter the uncertainties or changes in its dynamics, the tasks must be performed with due precision. As an example, in the

case of load transportation, the dynamic characteristics such as mass, center of mass and inertia, change when the robot is loaded. Then, to keep a good performance, the controller should be capable of adapting itself to this kind of changes. This adaptive capability is also important whenever it is difficult to model the system exactly, even without dynamic changes from task to task. Some works present the design of controllers that compensate for the robot dynamics. Fukao *et al.* (2000) propose the design of an adaptive trajectory tracking controller to generate torques based on a dynamic model whose parameters are unknown. In this work, only simulation results are shown. Other types of trajectory tracking controllers assuming uncertainty in the robot dynamics are developed by Liu *et al.* (2004), Dong and Guo (2005) and Dong and Huo (1999), with the performance shown just through simulations. Das and Kar (2006) show an adaptive fuzzy logic-based controller where the system uncertainty, which includes mobile robot parameters variation and unknown nonlinearities, is estimated by a fuzzy logic system and its parameters are tuned on-line. Bugeja and Fabri (2007) present the use of a *RBF-NN* for mobile robot dynamics approximation, in which the centroids remain fixed and the weights are estimated stochastically in real-time. The authors show simulation results.

Kim *et al.* (2000) have proposed a robust adaptive controller for a mobile robot divided in two parts. The first one is based on robot kinematics and is responsible of generating references for the second one, which compensates for the modeled dynamics. However, the adapted parameters are not real parameters of the robot, and no experimental results are presented. Additionally, the control actions are given in terms of torques, while usual commercial robots accept velocity commands. In (De la Cruz and Carelli, 2006) it is presented a linear parameterization of a unicycle-like mobile robot and the design of a trajectory tracking controller based on its complete known model. One advantage of their controller is that its parameters are directly related to the robot parameters. However, if the parameters are not correctly identified or change with time due, for example, to load variation, the performance of the controller will be severely affected.