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ADAPTIVE PID CONTROL FOR NONLINEAR SYSTEMS WITH A PARALLEL FEEDFORWARD COMPENSATOR

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Abstract. *In this paper, we propose a design method of an adaptive PID controller based on output feedback for nonlinear systems with a higher order relative degree and disturbances. To realize an adaptive PID control system, we introduce a PFC for a nonlinear system which does not satisfy OFEP(Output Feedback Exponentially Passive) conditions and design an adaptive feedforward input with a structure of RBF (Radial Basis Function) neural networks in order to remove the steady-state bias error from the PFC output. The proposed method has a structure of two degree of freedom and can design a robust adaptive PID control system with higher accuracy on tracking control.*
Keywords: PID control, Adaptive control, Adaptive neural networks, Parallel feedforward compensator

1. **Introduction.** In the recent decade, much attention has been paid to high gain output feedback-based adaptive controls for nonlinear systems due to their simple structure and high robustness with respect to uncertainties and disturbances [1, 2, 3]. The most typical design condition for designing the output feedback-based adaptive control is recognized as the output feedback exponentially passive (OFEP) condition [3]. This condition is well known as the ASPR condition for linear systems [4]. Unlike other adaptive methods, under the OFEP (or ASPR) condition, one can easily design an output feedback-based adaptive controller without a priori information of the order of the controlled system and without designing a state observer.

Recently, auto-tuning and adaptive PID control strategies based on the almost strictly positive real (ASPR) property of the controlled system have been proposed [8, 9] for linear systems. The PID control is one of the most common control schemes applied to many industrial processes and mechanical systems. Since the control has played a very important role in the improvement of production quality in accuracy and reducing production costs, a great deal of attention has been turned to auto-tuning PIDs including self-tuning schemes and adaptive control strategies [5, 6, 7, 8, 9, 10] in order to maintain the desired control performance and stability during operation.

In this paper, we propose an adaptive PID control system design scheme for nonlinear systems utilizing the output feedback exponential passivity (OFEP) [3, 11] of the controlled system. The sufficient conditions for the system to be OFEP are that (1) the system is globally exponential minimum-phase, (2) the system has a relative degree of 1 and (3) the nonlinearities of the system satisfy the Lipschitz conditions [3]. Unfortunately,