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PSO-BASED SIMULTANEOUS TUNING METHOD FOR PID CONTROLLERS AND DEAD-ZONE COMPENSATORS AND ITS APPLICATION TO ULTRASONIC MOTORS

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Abstract. *This paper proposes a simultaneous tuning method for PID controllers and dead-zone compensators based on particle swarm optimization. By the proposed algorithm, PID gains and dead-zone parameters are tuned online to minimize the error between the control output and the reference input. However, since ultrasonic motors intrinsically have a varying dead-zone in the control input associated with applied load torque, dead-zone compensation is required for precise control of these motors. The proposed method is applied to an ultrasonic motor, and its effectiveness is verified by experimental results.*
Keywords: Particle swarm optimization, Ultrasonic motor, PID control, Dead-zone

1. **Introduction.** Proportional-integral-derivative (PID) controllers are widely used in many fields because they are simple and effective. Although many methods for tuning the three gains of PID controllers have been extensively investigated thus far, this kind of research is still approached actively from computational aspects, *e.g.*, [1, 2]. One of the reasons is that the optimization problem for determining optimal gains of a PID controller is generally nonconvex, and therefore, solving it globally is difficult.

Particle swarm optimization (PSO) has recently received considerable attention as an effective global optimization tool and has been applied to PID control problems [3]. Although the PSO-based PID controller tuning method in [3] has been shown to be more effective than the existing methods, it has to be implemented offline. Since such an offline method requires a plant model in most cases, a method for system modeling is required and causes another issue such as modeling error compensation. Practically, therefore, an online tuning method without any plant models is desirable [4].

From another viewpoint, PID controllers are not always effective for systems with nonlinearities such as a dead-zone. Since ultrasonic motors (USMs) intrinsically have varying dead-zones in the control input that are associated with applied load torque, dead-zone compensation is required for precise control of these motors. To this end, a control method for tuning PID gains based on fuzzy inference has been proposed [5]. However, it requires offline calculation under some experimental conditions.

To overcome the abovementioned problems, we propose a simultaneous tuning method for not only PID controllers but also dead-zone compensators using PSO. Our approach