DC servomechanism parameter identification: A closed loop input error approach
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ABSTRACT
This paper presents a Closed Loop Input Error (CLIE) approach for on-line parametric estimation of a continuous-time model of a DC servomechanism functioning in closed loop. A standard Proportional Derivative (PD) position controller stabilizes the loop without requiring knowledge on the servomechanism parameters. The analysis of the identification algorithm takes into account the control law employed for closing the loop. The model contains four parameters that depend on the servomotor inertia, viscous, and Coulomb friction as well as on a constant disturbance. Lyapunov stability theory permits assessing boundedness of the signals associated to the identification algorithm. Experiments on a laboratory prototype allows evaluating the performance of the approach.

1. Introduction
Direct Current (DC) servomotors are widely employed in industry; examples of their application include computer-controlled machines, robots, and process control valves. Modern digital servodrives used for controlling these actuators perform tuning automatically using real-time data. This procedure is composed of three sequential steps. In the first step, a parameter estimation algorithm identifies a model of the servomotor. In the second step, the parameters obtained in the first step, allows computing a control algorithm. In the third step, the servomotor works using the control algorithm computed in the second step. Regarding the design of the control law, there exist a great number of designs including Proportional Derivative (PD) and Proportional Integral Derivative (PID) controllers. On the other hand, even if there exists a lot of work concerning parameter identification [1,2], most of the proposed algorithms deal with open loop stable systems. In this regard, note that a second order model of a position-controlled servomotor is not bounded-input bounded-output stable. Moreover, if parameter identification is performed when the servomotor is coupled to a mechanical load, for example to a robot arm, closed-loop identification with the loop closed around a position sensor would be undesirable for security reasons since open loop techniques would lead to unbounded motor behavior.

Several papers propose methods for closed-loop identification of position-controlled servomechanisms [3–11]. In [3], the authors propose an internal model controller designed from results obtained using off-line identification algorithms. An off-line least squares method allows tuning a two degrees-of-freedom linear controller in [4]. In [5], the authors employ a disturbance observer to obtain discrete-time estimators for the servomotor inertia and viscous friction which in turn are employed for obtaining Coulomb friction estimates. It is worth noting that the authors evaluate performance of the proposed estimators through experiments. In [6], a recursive multi-step extended least squares permits identifying a linear discrete-time model of a servo. The servo input and output feed the estimation algorithm and a proportional controller closes the loop. According to the taxonomy given in [12], the approach proposed in [6] would correspond to a direct approach where the controller is ignored for identification purposes. It is also worth noting that the authors do not give a convergence analysis of the identification algorithm.

Relay-based techniques are widespread for servo identification [7–11]. The idea behind these methods, which is similar to the relay tuning methods in process control [13], is to close the loop through a relay in order to obtain a sustained oscillation; then, its amplitude and frequency allow identifying linear and nonlinear servomodels. A drawback of relay-based techniques is the fact that tuning of the relay controller can be cumbersome and the methods proposed in the literature do not provide a systematic tuning procedure of the relay controller.

Refs. [14,15] study several identification algorithms applied to linear discrete-time plants. These methodologies termed as the Closed Loop Output Error (CLOE) algorithms have several advantages with respect to traditional closed loop identification methodologies. They are able to produce unbiased estimates; moreover, the controller used for closing the loop has a prime role in the identification procedure, and iterative tuning procedures accommodate easily within these methodologies. Moreover, real-time experiments using laboratory prototypes validate these approaches.