Compliant Robot Behavior using Servo Actuator Models identified by Iterative Learning Control

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Abstract. System parameter identification is a necessary prerequisite for model-based control. In this paper, we propose an approach to estimate model parameters of robot servo actuators that does not require special testing equipment. We use Iterative Learning Control to determine the motor commands needed to follow a reference trajectory. To identify parameters, we fit a model for DC motors and friction in geared transmissions to this data using a least-squares method. We adapt the learning method for existing position-controlled servos with proportional controllers via a simple substitution. To achieve compliant position control, we apply the learned actuator models to our humanoid soccer robot NimbRo-OP. The experimental evaluation shows benefits of the proposed approach in terms of accuracy, energy efficiency, and even gait stability.

1 Introduction

DC servo motors are popular actuators in the field of robotics because of their ease of use and low cost. Traditional control methods often ignore the dynamics of the motor, in particular friction forces, and compensate the loss of knowledge about the system through sensory feedback. While it is possible to reach very small position errors with this method, high-gain position control often results in undesirable behavior like stiffness and oscillations (limit cycles).

The research field of humanoid soccer robots places unique demands on the performance of robot joints. Having the ability to perform highly dynamic motions is more important than accurate setpoint tracking at low speeds. These motions require considerable torques and moments and can be dangerous to the joint—in particular to the gear—if not executed properly.

The use of motor and friction models enables the controller to demand exactly the torque needed to follow a position trajectory. In addition to minimizing energy consumption, this leads to a more compliant motion of the robot in the face of unexpected obstacles or perturbations—a feature that is important in many robot applications.

Determining motor model coefficients can be a daunting task, since specific test runs in controlled situations are needed. Often the motor cannot remain in the robot for parameter measurement. Additionally, special test setups might