ITERATIVE LEARNING CONTROL FOR NONSMOOTH DYNAMICAL SYSTEMS

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ABSTRACT

Iterative learning control (ILC) is a control technique that improves the performance of dynamical systems working in a repetitive mode. ILC emulates the human capability of learning from practice. In the same way a tennis player improves the shots after practicing over and over, an iterative learning controller uses previous trial information to get better performance of a system with respect to some desired performance objective.

ILC has been applied to robots performing repetitive tasks, where it has proven to be effective in compensating nonlinear effects such as gravity, Coriolis, and centrifugal forces. ILC has also been used in many other applications, e.g., batch chemical processes, injection molding machines, power electronics, and aerospace, to mention a few. However, ILC for nonsmooth dynamical systems has not been extensively explored. There has been some applications and heuristic procedures but not an analytical study for those cases. Examples of nonsmooth dynamics can be found in mechanical systems with dry (Coulomb) friction, systems with intermittent contacts, e.g., in robot assembly and walking robots, switching controllers such as in gain scheduling control, systems with backlash, systems containing discontinuous actuators like relays and solenoid valves, system with hysteresis, and switchings in electronic circuits. They are also present in economics and biology.

In this thesis, we analyze the implementation of ILC to nonsmooth dynamical systems. Two approaches for the design of ILC update laws are considered. The first approach is based on the application of the passivity theory. Derivation of the convergence of proportional ILC algorithms for nonsmooth systems containing incremental sector bounded nonlinearities is presented for the first time. The second approach uses the optimal control theory. Optimal control based ILC algorithms for nonsmooth Lipschitz continuous dynamical systems are derived and a new ILC algorithm capable of generating piecewise-continuous inputs for nonsmooth dynamical systems containing discontinuities is developed. As application examples, these ILC algorithms are tested on mechanical systems with intermittent contacts and on mechanical systems with dry friction.