MMAR 2016 Meeting

Repetitive process control as a dynamic optimization problem

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The author offers a paradigm shift in repetitive process control. Iterative learning controllers are traditionally designed using the linear matrix inequality (LMI) approach. Consequently, their structure is often limited to a local or wave control law and as such they equally often suffer from instability in the long run if a repetitive exogenous disturbance of a sufficiently high bandwidth is present. Low-pass filtering is then necessary to prevent overlearning and make the controller practical. Those controllers are tuned in the offline mode and the relevant optimization is based on the availability of an approximate mathematical model of the plant. It is proposed here to harness the repetitiveness of the process for posing a dynamic, i.e. online, optimization problem (DOP). This problem is then solved iteratively using a proper gradient-free, gradient-based or hybrid part-stochastic part-deterministic evolutionary algorithm. The plant itself serves the role of the critic, thus the quality of control is not prone to deterioration due to plant parameter uncertainties. The update law is of a global type and any potentially harmful overlearning can be easily tackled with an appropriate cost functional definition or a limited control signal generator bandwidth. The robustness can be straightforwardly shaped by respective penalty factors in the cost functional. All in all, in the proposed paradigm, the optimization algorithm becomes itself the control algorithm and the behaviour of the system in the pass-to-pass direction is shaped by the designer tweaking the cost functional. It is demonstrated that such a DOP-based direct control system can be facilitated using artificial neural networks accompanied by an error backpropagation training algorithm or particle swarms along with their stochastic search mechanisms. Additionally, the stochastic search rule can be augmented with the classic deterministic P-type learning law to get better responsiveness, while keeping all the benefits of the evolutionary optimization approach. A family of **hybrid part-stochastic part-deterministic iterative learning control** laws is then born. Currently tested applications include control in power electronics and electric drives. It is also shown that DOP-based non-deterministic repetitive control is practical in terms of its computational complexity even at 10 kHz sampling as far as decent off-the-shelf digital signal controllers are considered.

Keywords: repetitive process control, iterative learning control, dynamic optimization problem, repetitive disturbance rejection, particle swarm optimization, artificial neural network, error backpropagation, hybrid part-stochastic part-deterministic iterative learning control.

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