Overview of Iterative Learning Control

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1 Origin of iterative learning control

Iterative learning control (ILC) originated in 1978 with the publication in Japanese of an article by M. Uchiyama (Uchiyama, 1978). In 1984, Arimoto et al. (Arimoto et al., 1984) first introduced the method in English. ILC can also be traced back to the US patent 3555252 by Murray in 1967 (Murray, 1967), and also to Edwards in 1974 (Edwards, 1974). These contributions are widely considered to be the origins of ILC. Since the 1990s, research activities in ILC have exponentially increased, as reflected in the increase of publications, special issues and conferences dedicated to many different applications related to ILC.

2 Main notion of iterative learning control

Learning is a technique that has been extensively used to control repetitive tasks. Iterative learning control is an intelligent learning control technique that incorporates past control information – such as tracking errors and control input signals – into the construction of the present control action to improve tracking performance in the current iteration. In other words, not much information about the plant is required; it may even be completely unknown. Additionally, ILC differs from adaptive control, which also learns from previous operation information. Adaptive control adjusts the parameter of a given controller, while ILC aims to construct the input signal directly.

ILC is developed for control tasks that repeat in a fixed and finite-time interval, and requires only the system gradient bound instead of an accurate system model. Most practical plants only have nominal models instead of accurate models, which gives ILC great potential for practical applications. Thus, using ILC, the system can finish a task in a limited time and can be reset to the same initial value, and the tracking objective is iteration invariant

ILC can be classified into two types (Wang et al., 2009): direct ILC, which means the design integrates the feedback and the feedforward control through the closed-loop controller; and indirect ILC, which implies that either the feedback or the feedforward control could be implemented through different controllers and may be designed independently.

A recommended starting point for the literature on ILC is some of the survey papers by Bonvin et al. (Bonvin et al., 2006), Ahn et al. (Ahn et al., 2007), Wang et al. (Wang et al., 2009), and Freeman et al. (Freeman et al., 2015).

3 Iterative learning control applications and future directions

ILC has become one of the most effective control methodologies, especially in dealing with repeated tracking control problems or periodic disturbance rejection problems. It has been widely used in industry, for example, in chemical reactors, injection-moulding machines, aluminium extruders, batch processes, robotic manipulators, trajectory tracking, high-precision CNC machining, induction motors, hard disc drives, milling and laser cutting, chain conveyor systems, traffic flow control systems, complex stochastic systems, rapid thermal processing and rehabilitation robotic systems.

Although ILC has been successfully applied in industry and other areas, there are still many challenges to be addressed, including difficulties encountered in ILC implementation due to hardware constraints. It is therefore important to develop ILC algorithms compatible with existing hardware functions or limitations. The fundamental problem of robust design in the presence of model uncertainty is a further challenge, along with disturbance and noise rejection and the development of new analysis tools. Another future research topic is the question of how to achieve controller order reduction for ILC design.

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