Iterative Learning Control: Analysis, Design, Integration & Applications

ITERATIVE LEARNING CONTROL

Analysis, Design, Integration and Applications

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Preface

Iterative Learning Control (ILC) differs from most existing control methods in the sense that, it exploits every possibility to incorporate past control information, such as tracking errors and control input signals, into the construction of the present control action. There are two phases in Iterative Learning Control: first the long term memory components are used to store past control information, then the stored control information is fused in a certain manner so as to ensure that the system meets control specifications such as convergence, robustness, etc. It is worth pointing out that, those control specifications may not be easily satisfied by other control methods as they require more prior knowledge of the process in the stage of the controller design. ILC requires much less information of the system variations to yield the desired dynamic behaviors. Due to its simplicity and effectiveness, ILC has received considerable attention and applications in many areas for the past one and half decades. Most contributions have been focused on developing new ILC algorithms with property analysis.

Since 1992, the research in ILC has progressed by leaps and bounds. On one hand, substantial work has been conducted and reported in the core area of developing and analyzing new ILC algorithms. On the other hand, researchers have realized that integration of ILC with other control techniques may give rise to better controllers that exhibit desired performance which is impossible by any individual approach. Integration of adaptive, robust or other learning techniques into ILC for various control problems has been frequently reported to remove usual requirements on conventional ILC algorithms. The research of ILC has even seen "invasion" into areas which were traditionally non-control areas. For instance, iterative learning schemes have been used to improve system identification or curve fitting. However, it was only in the Second Asian Control Conference held in Seoul, Korea in July 1997, that the ILC reached the greatest milestone ever since its birth in 1984.

There were more than 30 dedicated or highly relevant papers being presented in the Second Asian Control Conference. There were five invited sessions and one invited panel session in which ILC experts from all over the world exchanged their opinions and discussed the past, present and future of

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ILC. Presentations and discussions covered a very wide spectrum of ILC topics including robustness, design methodology, combination with neural/fuzzy approaches, discretization problems, new ILC algorithms, new ILC property analysis, direct learning, as well as applications to both motion control and process control problems.

These new achievements and new trends warrant an edited book devoted to the research in ILC, which is earnestly needed for the researchers and engineers in the fields of control, automation and signal processing. The goal of this dedicated book is twofold. First, it aims to summarize the state of the art in the area of ILC research. Second, it points out directions perceived as the most important ones for the future. In some sense, this book serves as an invitation to all the practical control engineers and academic researchers to examine and evaluate the merits of iterative learning control from their own respective domains of research and applications.

In compiling the eighteen chapters in the book, we have chosen five categories of material to form five parts. The first group of chapters (Part I: Chapters 1-2) gives general introduction on ILC. Chapter 1 briefly describes the historical development of iterative learning control. Chapter 2 oversees and examines the current status of ILC, as well as points out directions for future efforts. The second group of chapters (Part II: Chapters 3-6) focuses on ILC property analysis. Chapter 3 focuses on the robustness and convergence properties of a PD-type iterative learning controller. Chapter 4 explores the connections between the learnability and the system passivity/dissipativity. Chapter 5 discusses the convergence condition of ILC under the sampled-data environment. Chapter 6 examines the discrete time iterative learning control with current iteration error feedback. The third group (Part III: Chapters 7-10) deals with basic ILC design principles. Chapter 7 documents the critical engineering design issues in applying ILC to practical systems. Chapter 8 addresses ILC design problems in the presence of uncertain system delay and initial state error. Chapter 9 studies how to design ILC algorithms using quadratic criterion and state observation. Chapter 10 suggests the utility of structured singular value and linear fractional transformation for ILC design for unstructured and/or structured uncertainties. The fourth group (Part IV: Chapters 11-15) shows possible integration of ILC with other intelligent control schemes. Chapter 11 illustrates the combination of ILC and Wavelet to achieve the target of tracking non-uniform trajectories. Chapter 12 considers the integration of ILC with neural network to achieve the general interpolation property for difference trajectories and meanwhile to update learning gains. Chapter 13 presents an ILC scheme for robotic dynamics by synthesizing adaptive control and ILC approaches, which is further generalized by using fuzzy basis functions. Chapter 14 introduces a new learning control scheme – direct learning control which directly generates the desired control signal in a pattern-based learning manner without repetition process. Chapter 15 summarizes how system identification can be merged with ILC to improve learning and control performance. The fifth group (Part V: Chapters 16-18) is devoted to solving process control and motion control problems using ILC. Chapter 16 attacks batch process control problems, e.g. the temperature control of a batch reactor, by combining model-based predictive control with ILC. Chapter 17 develops a specific ILC scheme to handle Gas-Metal Arc welding problem which is characterized by non-uniform trial length and random initial values. Chapter 18 demonstrates the effectiveness of discrete-time iterative leaning for the control of a functional neuromuscular stimulation system which is highly nonlinear and non-affine.

It is a pleasure for us to acknowledge those who have helped make this edited book possible. First we would like to thank all chapter authors. Mission would be impossible without their full support and contribution. We would also like to take the opportunity to thank Dr. Kwang-Hyun Park and Dr. Chen Yangquan for their insightful comments. Special appreciation is extended to Dr. Chen Yangquan who helped do all documentary work. We would particularly like to thank Dr Alexander Greene, Kluwer Publisher, whose support, encouragement and expert guidance led the project to a successful ending.

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