The IEEE Control Systems Society (CSS) Technical Committee on Intelligent Control (TCIC) was established in 1985 to foster a community and to provide forums for the theoretical and practical considerations of intelligent control techniques and their application to devices and systems. From its inception through the turn of the millennia, rapid advancements established cornerstone techniques for incorporating intelligent control techniques within feedback control approaches. For example, fundamental contributions to our understanding of how to use Lyapunov-based analysis methods to inform the design of gradient and least-squares adaptive update laws and modular and composite adaptive control were established. Neural networks (NN) and fuzzy logic (FL) were transformed from computational tools used for pattern matching based on a finite set of training data to powerful function approximation tools that used backpropagation with adaptation through online state feedback. Iterative (ILC) and repetitive learning control (RLC) methods were developed and matured, and various methods were developed for improved transient performance during adaptation and simultaneous parameter identification. Refinements, generalizations, and the application of these methods are still on-going areas of research.

The aforementioned intelligent control techniques have been successfully absorbed into mainstream control systems research. Adoption of intelligent control within control communities is evident from the number of conferences across several societies that include multiple sessions on adaptive control, ILC/RLC, NN, FL, and applications of such tools. Evidence of the impact of intelligent control is also provided by industrial adoption of machine intelligent, machine learning, and artificial intelligence driven technologies in a wide spectrum of control applications such as autonomous vehicular systems, energy management (e.g., wind field prediction) and distribution (e.g., smart grids), automated farming and plant health monitoring, machine interactions with uncertain biological systems (e.g., rehabilitation engineering, smart prosthetics), and networks of uncertain systems (e.g., cyber physical systems and the internet of things).

Such new application domains are driving a resurgence in interest and activities in intelligent control that some members of the TC have coined "Intelligent Control 2.0". For example, similar to the early stages of NN/FL development, deep learning methods are still largely limited to pattern matching results where weighted connections are adjusted offline from a finite training set, generally through heuristic algorithms. New opportunities exist to understand how the multiple layers of weight updates can be updated online through state feedback dictated from a stability analysis that provide insights into convergence and stability. Deep learning methods also raise questions related to computational capabilities and strategic approaches to take advantage of learning and adaptation across multiple time scales. New insights from data-based learning (e.g., concurrent learning, experience replay) and state extrapolation (i.e., simulation of experience) are shedding new insights into less stringent (finite and on-line verifiable) excitation conditions for simultaneous control and parameter identification.

Members of the TCIC have also lead the incorporation of machine learning concepts such as actor-critic-based reinforcement learning (RL) and Q-learning methods within analysis frameworks for stability and convergence, with outcomes such as approximate optimal control in the presence of uncertainty. For example, distributed RL approaches are being examined where agents learn to teach by communicating action advice, thereby improving final performance and accelerating teamwide learning. Distributed RL is also being examined through differential game frameworks. Motivated by computational demands associated with RL, new functional approximation methods are being investigated that require less kernels (e.g., State-Following (StaF) kernels), encode more information within the kernels (e.g., occupational kernels), or exploit sparsity for targeted learning (e.g., sparse NN).

Various communities are motivated to develop and use hybrid and switched systems tools to examine applications that involve a mix of continuous and discrete dynamics. Likewise, TCIC members are interested in understanding the impact of such dynamics on learning. For example, aforementioned approaches such as sparse NN, data extrapolation/simulation of experience, concurrent learning, and others involve continuous physical dynamics coupled with discrete information dynamics. Open questions remain regarding the fusion of hybrid systems analysis tools with adaptive/learning methods that include technical challenges (e.g., non-strict Lyapunov function candidates) that typically result in asymptotic convergence. For example, TCIC researchers are investigating analysis methods that involve dwell-time conditions (especially for switching between unstable and stabilizable subsystems) when convergence rates are uncertain due to uncertain learning rates. Similar to the discrete nature of information dynamics, task specifications are often also defined by a discrete set of logical actions. Hence, open questions are also being investigated with regard to the ability to synthesize intelligent control methods using formal method frameworks.

Answers to such new theoretical domains can have an impact in a wide range of new applications. Advances in system identification and fault detection approaches can potentially lead to new cyber defense or forensic tools against cyber effects. Government and industrial sectors are heavily investing in a variety of applications where (semi-)autonomous systems are tasked with operating in complex environments (e.g., automated driving, military applications) where sensing/feedback may be uncertain, denied/intermittent, or attacked/spoofed. Yet, significant questions arise for trusted, guaranteed, or assured behaviors in the presence of uncertainty, especially when the uncertainty is being intelligently manipulated by an outside actor.

Such applications have resulted in large scale investments in programs generally described as "autonomy", where the (surface level) impression is that progress will result from advancements in artificial intelligence (AI). The TCIC has a long history of building bridges between the rigorous mathematical approaches of the control systems community with the insights from computational intelligence/AI to yield intelligent control systems with predictable behaviors.

The TCIC has 51 current active members that are focused on both the aforementioned traditional and Intelligent Control 2.0 open problems. The TCIC has been active in promoting invited sessions, workshops, and special issues in journals in recent years (e.g., "Parameter Convergence in Adaptive Control without Persistence of Excitation", "Recent Advances in Adaptive and Intelligent Control", "Game Theory Approach to Control and Optimization of Cyber-Physical Systems", "Design and Analysis Techniques in Iterative Learning Control", "Predictive Learning and Lookahead Simulation", "Distributed Reinforcement Learning and Reinforcement Learning Games", "IEEE Symposium on Reinforcement Learning and Adaptive Dynamic Programming"), along with disseminating recent advances through recent monographs (e.g., *Reinforcement*

Learning for Optimal Feedback Control: A Lyapunov-based Approach, Control of Complex Systems: Recent Advances and Future Directions, *Robust Adaptive Dynamic Programming*, *Cooperative Synchronization in Distributed Microgrid Control, Iterative Learning Control with Passive Incomplete Information: Algorithm Design and Convergence Analysis, Iterative Learning Control for Systems with Iteration-Varying Trial Lengths: Synthesis and Analysis)* various invited lectures, IEEE Distinguished Lectures, and Semi- and Plenary talks. Researchers interested in further information about intelligent control, or who would like to join the TCIC, are welcome to contact the TCIC chair. The TC website can be found at http://intelligent-control.ieeecss.org/intelligent-home, which provides a listing of the TCIC members and their activities.

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