# Editorial to the 50th Anniversary Issue

***Abstract*—A 50th birthday is an important milestone in the life of any individual and certainly in the development of collectives and organizations. January 2021 is such a milestone in the life of the IEEE TRANSACTIONS OF SYSTEMS, MAN, AND CYBERNETICS, which had its very first issue published in January 1971. Our 50th Anniversary Issue celebrates this remarkable achievement by introducing 20 survey articles from early pioneers of our field, as well as works by leading scientists conducting research at the cutting edge of systems science, with a focus on human aspects, cybernetics, with crucial societal impact. Our goal is to provide a vista of the remarkable developments in the past, giving a snapshot of the present state of our field, and indicating possible avenues for future progress in our rapidly changing research discipline.**

***Index Terms*—Adaptive systems, cognitive systems, cybernetics, evolving spatiotemporal systems, fuzzy systems, intelligent systems, large-scale systems, neural systems, social systems, systems engineering.**

## I. INTRODUCTION

THE FIELD of systems, man, and cybernetics has been forged more than 50 years ago as a result of the concentrated effort of leading scientists, who recognized the importance of the synergy between various scientific, engineering, and social disciplines, when addressing problems of crucial importance for the society, which often lose coherence by being fragmented in narrowly focused, specialized research areas.

It is remarkable to have this 50th anniversary for our journal and our SMC Society, while we experience an exponentially accelerating development of science and technology. Many of the advanced technologies which are readily available to all of us today, i.e., we hold them in our hands and keep them in our pockets, would have been considered outlandish science fiction 50 years ago. The fact that SMC maintained relevance for half a century in spite of all the rapid technological changes, shows that its founding principles address very deep, substantial human needs. It is impossible to provide a comprehensive account of all the relevant and very important contributions appeared in our Transactions for the past five decades, so we do not attempt it at all. Instead, we provide some examples of key developments with a long-lasting impact.

## II. SURVEY PAPERS BY EARLY PIONEERS FOLLOWING ON THEIR CLASSIC WORKS

### A. Introduction to the Anniversary Special Issue

This Special Issue (SI), which contains 20 survey papers in key research areas covered by our Transactions, is structured as follows. We start with an overview paper [item 1) in the Appendix] by leaders of the SMC Society on the development of systems science and engineering research in the context of SMC discipline. This work includes a scientometric analysis of the Transactions in the past 25 years, identifying trends and perspectives. Research in the first 25 years of our journal is not covered by that analysis, as properly cross-referenced publications are less readily available for the early years.

Following the introductory analysis by Tunstel *et al.* [item 1) in the Appendix], we have a section composed of invited surveys by early pioneers of our field. As a specific criterion of the selection, we searched for papers published in our Transactions, which have a high number of citations; high meant typically around or above 1000 citations for a single paper (Google Scholar metrics). Some of the early pioneers are not with us, like Zadeh, whose groundbreaking work [item 2) in the Appendix] presented the foundations of fuzzy systems, with over 11K citations. Some of the invited pioneers could not allocate time to this project, others could not be reached as they retired and did not respond to our request, while moved to a different research field that would not fit our Transactions. Several invited authors could not complete their work in time to make this issue; we look forward to publish their results in a consecutive edition.

### B. Surveys by Authors of Classic Landmark Papers

We received outstanding support from many early pioneers; their reviews are included in the first section of this SI. The first decade of our Transactions produced a large number of key achievements, which define our field until today. Among those, Haralick's paper [item 3) in the Appendix] on textural features for image classification is still one of the most influential works in our Transactions, having over 22K citations. His contribution to the present issue covers the extensions of the $N$-tuple method using a generalized product expression, related to generalizations of graphical models.

The year 1983 has been special in our Transactions, as an unusually large number of very successful and highly cited papers were published that year. The September/October 1983 issue has been a particularly singular event, a sort of phase transition in the life of the journal. It included the *Special Issue on Neural and Sensory Information Processing*, edited by Sanderson and Zeevi. Many authors became highly prolific following their work published in that very issue. Surveys from three of them [items 4)–6) in the Appendix] are included in our anniversary issue. Barto *et al.* [item 4) in the Appendix] laid out the foundations of reinforcement learning, which is at the forefront of many advanced AI techniques today. In this SI, Barto *et al.* analyze the circumstances leading to those discoveries and provide perspectives for future research. The

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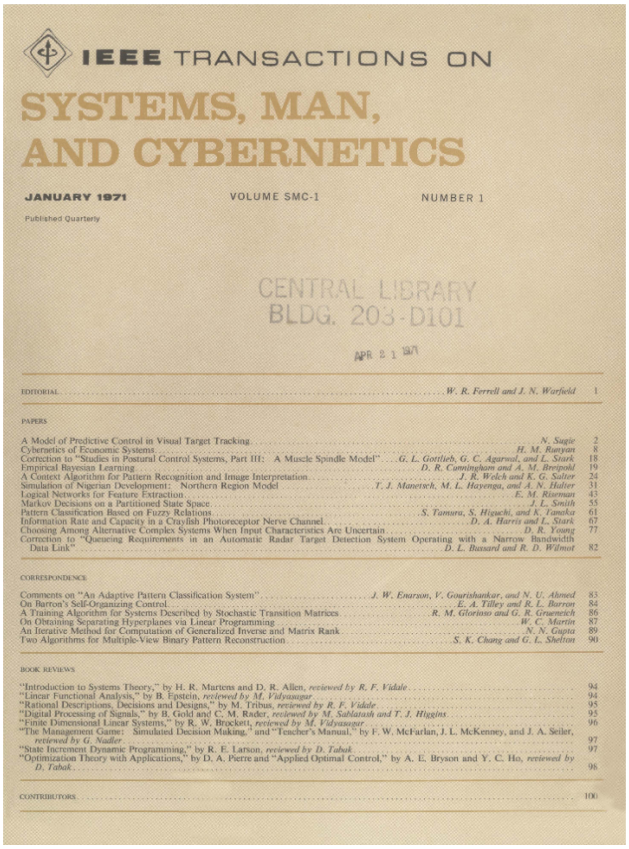

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Fig. 1. Front page of the very first issue of the IEEE TRANSACTIONS ON SYSTEMS, MAN, AND CYBERNETICS, on January, 1971.

work by Cohen and Grossberg [item 5) in the Appendix] studied the absolute stability of the global pattern formation and memories by competitive neural networks, which has been the starting point of many thousands of follow-up work on stability analysis in the past decades, many of which appeared in our Transactions. Grossberg's contribution to our issue addresses those early works and expands to general autonomous adaptive intelligence based on brain-like neural models. The third paper from that remarkable 1983 issue is by Fukushima *et al.* [item 6) in the Appendix] on neocognitron, which is still a golden standard of image processing. It lays at the heart of convolutional neural networks (CNN), which together with backpropagation (BP) [items 7) and 8) in the Appendix], are the key components of today's mainstream deep learning technology [item 9) in the Appendix].

The fuzzy $k$-nearest neighbor clustering algorithm has been introduced in 1985 by Keller *et al.* [item 10) in the Appendix], which is widely used and extended in the ensuing decades [item 11) in the Appendix]. In our SI, Keller and Bezdek go beyond static clustering algorithms and provide an overview of streaming data analysis. Bidirectional associative memories (BAMs) by Kosko [item 12) in the Appendix] are widely employed in machine learning for over three decades, following their publication in 1988 in our Transactions. This SI features an article about the generalization of BAMs using Hebbian learning, together with various applications of this tool. Following Yager's highly influential work on ordered weighted averaging (OWA) aggregation operators for decision making [item 13) in the Appendix], OWA operators have been generalized in multiple ways, including by Yager and Filev [item 14) in the Appendix]. In this SI, Filev *et al.* describe fuzzy-encoded Markov chains (FEMCs) and their applications in forecasting and control. The first section of the SI ends with an extensive overview of graph models for conflict resolution and decision support by Fraser and Hipel, following the foundational research published in our Transactions since the 1970s [item 15) in the Appendix]. This line of work is closely related to the original goal statement of the Transactions to link computational modeling of human behavior, and to support action and decision making.

### *C. Cutting-Edge Modern Topics in SMC Systems Engineering*

Our Anniversary Issue aims to provide a snapshot of several cutting-edge fields, which were at the very incipient phase when our Transactions started, or did not exist at all until the recent 10–20 years. We group these advances into computational, algorithmic advances, and hardware embodiments, respectively.

*1) Computational and Algorithmic Breakthroughs:* A range of advanced intelligent control techniques became highly successful areas where our Transactions has a leading role, including the sliding-mode control, tracking control, multiagent control, networked control, fault-tolerant control, event-triggered control, and related areas. It is impossible to cover all these advances in a single SI, and the readers are directed to previously published SIs in specific areas. We plan to have a follow-up to this SI with a focus on advanced control methods. In the present SI, we illustrate the leadership of our Transactions in a few topics.

Dynamic programming and game theory have been fundamental unifying theories of optimization [item 16) in the Appendix], which significantly contributed to the emergence of the SMC field. Approximate or adaptive dynamic programming (ADP) has become a highly fertile research area in recent decades. Our SI features a survey by Liu *et al.* on ADP for selected control applications. This is followed by a survey on distributed intelligent control of multiagent systems by Shi *et al.* State estimation has been an important research area for our Transactions in recent decades, and Wang *et al.* provide a survey in the context of the control of cyber-physical systems. Fuzzy systems research has been a driving force for our Transactions since the beginning, and the paper by Herrera-Viedma *et al.* reviews recent developments of fuzzy decision making and consensus. The work by Chen *et al.* provides an overview of the explosively growing field of deep learning and broad learning.

*2) Revolutionary Advancements in Hardware Domains and Embodiments:* Our Transactions is very active in the field of the Internet of Things (IoT), which revolutionizes not only engineering and technological disciplines but also has a crucial impact on our society in the broad sense. Fortino *et al.* provide a review of IoT developments from a systems engineering perspective. Blockchain-secured systems are very important

for the reliable development of hardware and software technologies in the years to come. Liu *et al.* give a survey on these technologies in the context of smart manufacturing in Industry 4.0. Autonomy and intelligent vehicles are another hot topics today with many challenges. A special aspect of this field, related to human–computer interactions reviewed by Wang *et al.*, describes the state-of-the-art of the field and provides a glimpse to the possible future.

Robotics has been an important research discipline featured by many groundbreaking papers in our Transactions from early on, e.g., locomotion by McGhee and Iswandhi in 1979 [item 17) in the Appendix], and situated and embodied cognition by Brooks in the 1980s [item 18) in the Appendix]. Our SI features a survey by Karoly *et al.* on the application of deep learning in robotics, describing model structures and learning strategies. Another survey by Savur *et al.* addresses human–robot cooperation in the industry. Finally, the topic of wearable computers and brain–computer interfaces is addressed by Lin *et al.*, who describe crucial challenges due to the proliferation of advanced technologies in our daily life.

## III. Conclusion and Acknowledgment

IEEE TRANSACTIONS ON SYSTEMS, MAN, AND CYBERNETICS and its various offsprings have pursued advanced theoretical, computational, and engineering approaches to systems engineering for 50 years. The present Anniversary Issue provides a snapshot on this multifaceted research.

This Anniversary Issue is the result of a concentrated effort of many people; whose contribution we greatly appreciate. This includes the support of the leadership of the IEEE SMC Society, who provided the necessary means for this initiative. We thank all the authors who supported this initiative by providing their top quality surveys. We appreciate the work of the Associate Editors and reviewers who worked relentlessly to meet the often very tight deadlines. Special thanks are due to the editorial staff of our Transactions and IEEE Manuscript Central, as well as the staff of the IEEE Production Office, for their high-quality work, so we can celebrate this special anniversary.

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## Appendix
## Related Work

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