Guest Editorial From Complex Systems Science to Complex Systems Technology and Return: A Tale of an Endless Loop

The 20th century has been a time of revolution in many fields, from the sociopolitical world equilibrium to the mainstream theories and approaches in hard sciences. In particular, in physics, two pillars have tumbled down, changing definitely the way in which we think and represent the world where we live. The first issue on which we can no longer rely is *reductionism*; we now know that in many cases we cannot study the behavior of a system by breaking it down into simpler components because very often the behavior of the whole is much richer than the superimposition of the behavior of the components. The lack in *determinism*, on the other hand, makes us miss another element of certitude; a good model and a good estimate of the initial state of a system will make us able to predict its behavior for a very long, potentially infinite, time horizon. In the past, failed predictions only led to a conclusion: either the model was not accurate enough or the estimate of the initial conditions was wrong. At present, the fact that, given a system, reductionism and determinism cannot be taken for granted is of public domain, even outside of the scientific community. The unsuitability of the application of reductionism and determinism paradigms is one of the signatures of *complexity*. Others are strong nonlinearity, spatiotemporal multiscale phenomena, self-organization, self-repairing, and emergent phenomena.

A wide variety of complex phenomena has been investigated in the last century, from chaotic dynamics to fractals, from catastrophe theory to self-organized criticality, up to the most recent research on complex networks.

In complex systems, the property of emergence is really fascinating; a system, constituted by a high number of connected units, each of which has a rather simple individual behavior, exhibits complex behavior that cannot be explained on the basis of the individual laws regulating its individual constituents. Many scientists are devoting their research to unraveling the effects of the intriguing interplay between individual properties and network connectionism and its surprising outcome. This has generated a variegated scientific community, acting at the crossroads of many disciplines and able to create new ones.

An important milestone has recently marked a further revolution; the availability of huge databases of real-world data has fostered the move from research on toy models to that on real ones, in an attempt to reproduce or explain the data collected and made available to scientists all over the world.

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Meanwhile, industries are trying to deal with complexity to create new products. Up to ten years ago, even complex products were designed or controlled in order to mitigate or even cancel the signatures of complexity. Today, novel applications emerge in which complexity is not only taken into account but also exploited to make products with peculiar features, which generate added value in the fight for market chunks. Industries are involved in the design of systems that are scalable, robust, and adaptive, by making use of peculiar properties such as self-organization, repairing, and adaptation. Moreover, they are becoming aware that traditional approaches to design and engineering are failing to keep up with the increasing scale of present systems.

These are years in which we are witnessing the shift from complex systems science to complex systems technology. I am convinced that this shift will not be in a single direction, but that a virtuous loop is arising. On one hand, many concepts of complex systems science are being exploited to design and build systems with great features of robustness, scalability, adaptivity, etc. On the other hand, the artificial systems that are being built, together with the increasing availability of data, will lead to improvements in the understanding of complex phenomena. Observation of nature, in this loop, plays a fundamental role; by learning by nature, we build more and more effective artificial systems, which, in turn, help us to understand nature better and better.

This special issue arises from the experience gained while chairing the international conference COMPENG 2010 (Complexity in Engineering) in Rome, Italy, in February 2010, with the aim of gathering both scientists and people from industries to share their vision about the delicate shift from complex systems science to complex systems technology (and return). We had a great resonance in terms of participation and interest from several fields of research and industry. So, together with the members of the Steering Committee, whom I sincerely thank for the effort invested in this activity, we decided to propose to the IEEE SYSTEMS JOURNAL to host a special issue in which a selection of the best conference papers, plus excellent extra works submitted, were collected. The result is this volume, in which experts from many fields (from power systems to social networks, from automotive systems to military planning, and so on) gather together to provide the reader with their most advanced research on complex systems technology. I am grateful to all of them for submitting their papers, and to the referees for their collaboration.

I hope that the diversity in the disciplines and in the approaches presented in this volume will foster cross-fertilization and cooperation around the fascinating world of complex systems science and technology.

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