Complex adaptive communication networks and environments: Part 1

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Introduction

As modern networks grow in size, complexity and variety, the change in networks is not just terms of scale but also in the emergence of newer types of communication networks such as wireless sensor, ad-hoc, peer-to-peer (P2P), multiagent, nano-communication, mobile robot, Internet of Things (IoT), cloud-based and social networks. Various inherent nonlinearities in network operations can lead to an increase in complex emergent phenomena—phenomena whose effects are often untraceable to individual network components.

Such emergent patterns can be important to understand since they can have considerable unanticipated effects on various aspects of a network. These effects can range from unanticipated traffic congestion, an unprecedented increase in communication costs¹, to perhaps a complete network shutdown or grid blackout². Such phenomena thus require modeling communication networks by considering them instead as artificial Complex Adaptive Systems (CAS), or generalized collectively as Complex Adaptive Communication Networks and environments (CACOONS). Recent examples of the manifestation of ideas of complexity and emergence in CACOONS include cascading failures reported in the Amazon.com cloud³, effects of viral and worm infections in large networks⁴, emergence of cascading faults in message queue-based financial transactions after New Year’s Day⁵, network congestion and queue sizes⁶, effects of torrent and other complex traffic on company intranets⁷, multiplayer gaming⁸, multiagent systems⁹, self-organization and self-assembly in sensor systems¹⁰ and robotic communication networks and complex power networks¹¹.

Because of their peculiar nature, these ideas can be better modeled, simulated, analyzed as well as visualized using techniques developed as part of modeling and simulation of living or life-like or life-inspired complex systems—specifically, techniques and ideas previously explored by numerous multidisciplinary studies in the area of CAS¹². Unlike other modeling and simulation paradigms, Agent-based Modeling (ABM) offers a flexible general-purpose set of techniques for modeling complex phenomena ranging from the sciences to humanities. While ABM is often used to model the dynamic behavior in CAS¹³, Complex Network-based Modeling (CN) offers techniques to model interaction of different components using interaction datasets¹⁴ (especially big data¹⁵). Both these paradigms have been used extensively in the modeling of social, biological, ecological, archeological and other scientific domains, and recent work has demonstrated that these paradigms can also offer a much shorter learning curve and the ability to flexibly model complex phenomena in communication networks¹⁶. These techniques might be more effective for modeling and simulation of application case studies, testing of new communication protocols, investigation of problems before or after deployment or for modeling improvement in existing algorithms and hardware or for modeling communication of human or animal interaction in large-scale, hybrid, pervasive, mobile and social networks.

Papers

The special issue of Simulation on CACOONS received a total of 30 submissions, out of which 5 have been selected after peer review for Part 1.

In the first article, “Efficient and effective automated surveillance agents using kernel tricks” by Tarem Ahmed, Xianglin Wei, Supriyo Ahmed and Al-Sakib Khan Pathan, the authors use lightweight software agents based on kernel machines for automated visual surveillance systems for real-time intruder detection. The work demonstrates how to obtain high detection accuracy with low computational and storage complexities.

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The paper “Effects of leaders and social power on opinion formation in complex networks” by Mahdi Jalili focuses on communication in social networks. The author targets the evolution of opinion formation, in which the influence of leaders and social power is considered. Numerical simulations show that scale-free networks provide faster consensus compared to other networks.

The paper “A formal mathematical framework for modeling and simulation of wireless sensor network environments utilizing the hill-building behavior of termites” by Adamu Murtala Zungeru, Li-Minn Ang and Kah Phooi Seng focuses on the problems and inconsistency in the evaluation and validation of simulation studies for Wireless Sensor Networks (WSNs). The authors argue that simulation-based validation of WSN systems and environments should be further strengthened through mathematical analysis and formal frameworks.

The paper “A Pay-and-Stay model for tackling intruders in hybrid wireless mesh networks” by Al-Sakib Khan Pathan, Wafaa Mustafa Abdullah, Shapla Khanam and Habibullah Yusuf Saleem focuses on intrusion handling in Wireless Mesh Networks (WMNs). The authors propose an interesting approach to tackling intrusion by allowing an intruder to stay in the network as long as the stay is proved to be worthy by supporting the network’s regular activities. The proposed intrusion-tackling mechanism is termed a “Pay-and-Stay” model.

The final paper, “Model resolution in complex systems simulation: agent preferences, behavior, dynamics and n-tiered networks” by Eugene Ch’ng focuses on the model resolution of complex systems by means of an object-oriented communications framework. The work dissects individual agents with a view to modeling and simulating fine behaviors amongst a population of agent-types in n-tiered networks, scalable to hundreds of thousands of species using mathematically defined behavior, efficient algorithms and adaptive data structures as support for the simulations.

Acknowledgments

Producing a special issue undoubtedly involves a lot of work from the journal editorial staff, and the guest editors would like to acknowledge the invaluable work by various people who have made this special issue possible. These include Levent Yilmaz, Vicki Pate and the numerous reviewers that we had to call upon time and again for the peer review of the original and revised manuscripts. We would like to thank all of them for their timely efforts and continual support.

References


Author biographies

Muaz A. Niazi is a full professor at the Department of Computer & Software Engineering at Bahria University,
Islamabad. He is a senior member of the IEEE and is associated with various international societies such as the IEEE Robotics and Automation, IEEE Consumer Electronics and the IEEE Computational Intelligence societies. With an undergraduate honors degree in electrical engineering, Dr. Niazi has an MS and a PhD in computer sciences from Boston University and the University of Stirling, respectively, in addition to a postdoctorate from the Cognitive Signal-Image and Control Processing Research (COSIPRA) Laboratory at Stirling. Dr. Niazi’s research is focused on the modeling, simulation and engineering of complex adaptive systems. His current research interest is in the use of cognitive agent-based computing, a unified framework for agent-based and complex network-based approaches to modeling various types of complex systems in multidisciplinary areas such as communication networks, life sciences, social sciences and others. Dr. Niazi is the founding editor-in-chief of Complex Adaptive Systems Modeling, an Open Access journal as well as International Journal of Privacy and Health Information Management. He also serves as an associate editor for Cognitive Computation and Transactions on Emerging Telecommunication Technologies.

Amir Hussain obtained his BEng (with the highest 1st class honours) and PhD (with a resulting international patent on novel neural network architectures and algorithms) from the University of Strathclyde in Glasgow in 1992 and 1997, respectively. Following a postdoctoral research fellowship at the University of Paisley (1996-1998) and a research lectureship at the University of Dundee in Scotland (1998-2000), he joined the University of Stirling in 2000, where he is currently professor of computing science and founding director of the Cognitive Signal-Image and Control Processing Research (COSIPRA) Laboratory. He has (co)authored/edited more than a dozen books and over 200 papers to date in leading international journals and refereed conference proceedings. Since 2003, he has generated over €2m in research income (as principal investigator), including from UK research councils, EU FP6/7, international charities and industry. He is founding editor-in-chief of both Cognitive Computation journal and SpringerBriefs in Cognitive Computation, is associate editor for the IEEE Transactions on Neural Networks and Learning Systems and serves on the editorial board of a number of other journals. He has served as invited speaker, general/program (co)chair and organizing/programme committee member for over 50 leading international conferences to date. He is founding general co-chair of the annual International Conference on Brain Inspired Cognitive Systems (BICS’2004-2013) and the IEEE ICEIS’2006. He is chair of the IEEE UK and Republic of Ireland (RI) Industry Applications Society Chapter and a Fellow of the UK Higher Education Academy.