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Framework for Complex SoS Emergent Behavior: Evolution Using Deep Reinforcement Learning

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Abstract

Advances in technology have made it easy to integrate multiple modern systems to form complex system-of-systems (SoS) to achieve unparalleled levels of functionality that are otherwise not achievable by the constituent systems in isolation. In fact, with the recent explosion of machine learning techniques to build autonomous systems such as drones and self-driving cars, there is a pressing need to ensure that they collaboratively and safely operate in an SoS context. However, in general, the characteristic emergent behaviors of complex SoS -- that directly impact its operational measures of success or Measures of Effectiveness (MOEs) -- is very difficult, if not impossible, to manually explore, anticipate, and arbitrate just from knowledge of its underlying systems. Further, there are multiple scenarios of evolution in such complex SoS, including evolution in the emergent behavior of the SoS. The continuous, continual, and evolving nature of the SoS and constituent system environment's state and possible actions, adds further complexity. In this talk, we will present a novel approach that leverages Reinforcement Learning, a machine learning approach, to inculcate adaptable intelligence in constituent systems to adapt their behaviors in tandem with the evolution of emergent behavior at the SoS level. By augmenting the reward mechanism of RL with the SoS-Constituent System MOE Relationship -- that relates and ranks System MOEs vs. SoS MOEs -- we inculcate an Intelligent-Behavior Evolution Agent, with the necessary constraints to learn to maximize the SoS and system-level MOEs, while adapting itself to the evolution in SoS. We illustrate our approach and demonstrate its feasibility and potential using a Power Grid example.

Biographies

Dr. Ramakrishnan Raman received B. Tech and MS degrees from IIT Madras, and Ph.D. from IIIT-Bangalore. He is currently global Fellow at Honeywell Aerospace. He is a certified Six Sigma Black Belt and is INCOSE Certified Expert Systems Engineering Professional – ESEP, and an IEEE Distinguished Lecturer. He has 25+ years of extensive systems and software engineering experience in the Aerospace and Building/ Industrial Automation domains. He has to his credit several publications in refereed international conferences & journals on complex systems architecture design and Artificial Intelligence – Machine Learning. He is active in professional societies, including IEEE, INCOSE and SAE, and has also been the Technical Program Chair / Co-Chair for prestigious international conferences.

Dr. Anitha Murugesan received her B.E degree in Electrical and Electronics Engineering from University of Madras and M.Tech Degree in Computer Science and Engineering from Vellore Institute of Technology, India; as well as M.S and Ph.D. Degrees in Computer Science from the University of Minnesota, USA. She is currently an Sr. Scientist with the Advanced Technology group at Honeywell Aerospace, USA. Her research interests are requirements analysis, model-based development and formal verification of traditional and autonomous safety critical systems.