Deadlock-free Control of Automated Manufacturing Systems: A Petri Net Approach

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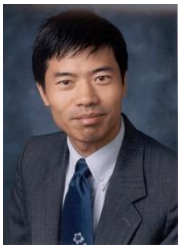
In automated manufacturing systems (AMS), deadlocks disrupt production and leave resources idle, thereby lowering efficiency. Deadlock avoidance policies outperform deadlock prevention and recovery strategies in terms of system throughput and resource utilization. For systems of sequential systems with shared process resources (S^4PR), which is a subclass of Petri nets (PNs) often used to model AMS, this work introduces a one-step look-ahead supervisory control approach to avoid deadlocks. First, deadlocks are identified through structural analysis. The states in S^4PR are classified as legal or illegal, with illegal states being those that cannot return to the initial one. By backward traversing a reachability tree from obtained deadlocks, legal states, called dangerous ones, that can reach illegal ones in just one step are detected. The above two processes are done offline during the system design phase. Subsequently, an online supervisor control strategy is designed to prevent illegal states. While an AMS is running, a supervisor determines the AMS's state by observing its behavior in real-time and compares the state with dangerous ones to guide the operation of the system, thereby ensuring that the system is live. In this supervisory control policy, for some observed behavior, the supervisor can directly make a correct decision without determining the state of the system. To further decrease the decision time of the supervisor, a set of minimal dangerous states is proposed to reduce the number of states that the supervisor needs to compare. Applying this policy results in a deadlock-free AMS that retains all legal states without altering the model structure and without requiring state-space traversal during system operation. This study enhances the application of PNs in AMS development to meet industrial needs.



MengChu Zhou received his B.S. degree in Control Engineering from Nanjing University of Science and Technology, Nanjing, China in 1983, M.S. degree in Automatic Control from Beijing Institute of Technology, Beijing, China in 1986, and Ph. D. degree in Computer and Systems Engineering from Rensselaer Polytechnic Institute, Troy, NY in 1990. He joined the Department of Electrical and Computer Engineering, New Jersey Institute of Technology in 1990, and is now a Distinguished Professor. His interests are in intelligent systems, robotics, Petri nets, Internet of Things, machine learning, and big data analytics. He has over 1300 publications including 17 books, over 900 journal papers including over 700 IEEE Transactions papers, 31 patents and 32 book-chapters. He is presently Senior Editor of IEEE Transactions on Intelligent Transportation Systems, and Associate Editor of Research, IEEE Internet of Things Journal, and Frontiers of Information Technology & Electronic Engineering. He is a recipient of Excellence in Research Prize and Medal from NJIT, Humboldt Research Award for US Senior Scientists from Alexander von Humboldt Foundation, and Franklin V. Taylor Memorial Award and the Norbert Wiener Award from IEEE Systems, Man, and Cybernetics Society, and Edison Patent Award from the Research & Development Council of New Jersey. His work have received over 78800 GoogleScholar citations with h-index being 141. He is Fellow of IEEE, International Federation of Automatic Control (IFAC), American Association for the Advancement of Science (AAAS), Chinese Association of Automation (CAA) and National Academy of Inventors (NAI).