A Specification Method for Desirable Controlled Behavior for Supervisory Control Logic Synthesis of a Multi-Robot Assembly Cell

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Abstract

We discuss a way of synthesizing supervisory control logic for a multi-robot assembly cell that satisfies logical control requirements or constraints, such as freedom from deadlocks, livelocks, collisions, and other wasteful or absurd behaviors. Once the desirable behavior of a discrete event dynamic system like the robot cell is specified as an automaton, called a legal language or a legal automaton, the desired supervisory control logic can be derived from the legal automaton by using recent supervisory control logic synthesis methods based on the language theory. However, specifying the control requirements as an automata or automata is nontrivial, especially for complicated systems like multi-robot assembly cells, which are subject to livelocks. We propose a practical method of efficiently deriving the legal automaton. We first model the system by specifying the behavior of each physical component or each control requirement as an automaton, except the deadlock-free and livelock-free requirements that are hard to be modeled by automata. To reduce the computational complexity for combining those component automata, we apply trim operations of removing dead-ended states or unreachable states for each component automata before shuffling them. We then shuffle the trimmed automata, which are often much smaller than the original ones, into a global automaton. To do this, we prove that the trim operation is interchangeable with the shuffling operation. From the composed global automaton, we derive a livelock-free sub-automaton to be a legal automaton by identifying the reachable transition paths from the initial state to the marked state. We apply the method to synthesizing supervisory control logic for a complicated multi-robot assembly cell.