Short introduction to Supervisory Control Theory and Model-Based Systems Engineering methods

Laurent Piétrac

1 Supervisory Control Theory

A Discrete Event System (DES) is a dynamic system in which state changes occur in response to the occurrence of certain events. At any state of the system, a number of possibilities are offered for the next event, which is taken nondeterministically and the state updated accordingly. Examples of discrete-event systems can be found in manufacturing systems, communication networks, embedded systems and traffic systems. In general, discrete-event systems are suitable for modeling the logical (high-level) aspects of any dynamic system.

Synthesis is a generic term that covers all procedures aiming to construct from specifications given as inputs objects matching these specifications. In the field of DES synthesis, Supervisory Control Theory is the most important theory used to construct controllers or controlled systems.

Supervisory control of DES was introduced by Ramadge and Wonham [17]. The behavior of a plant is modeled by a language $L$, and the set of legal event sequences, or behaviors, is specified by a language $E$. In general, it does not have to be the case that $L \subseteq E$, i.e., the plant has the potential to generate illegal event sequences. The goal of supervisory control is to eliminate such behavior. The possibility of control is provided by partitioning the set of events into controllable and uncontrollable events. Controllable events can be turned on and off by a supervisor which actively monitors the system and can intervene at any point in time in order to prevent unwanted behavior.

In order to make our design amenable to computation, and must have finite representations. Assuming that they are regular, each can be generated by a finite deterministic automaton. It is shown in [23] that in this case a minimally restrictive supervisor can be computed in time polynomial in the size of the plant and specification automata.

In current algorithms, the space (and time) required are exponential in the number of plant components and control specifications included in the DES model. Researchers are, therefore, seeking effective control methods for various subclasses of DES that enjoy special structure. Such structure will admit modularity [21] [5] [12], [9], [6] and model abstraction [22] [10], [8], to circumvent computing global dynamic models.

Examples of SCT application can be found in [18] [19] [3] [2] [7] [14].
2 Model-Based Systems Engineering methods

Whether it is a hybrid vehicle, a manufacturing system, an energy distribution network or a cell phone, today’s systems are expected to perform at level undreamed at a generation ago. This increased capability drives requirements for increased fonctionnality, interoperability, performance and safety.

The practices to develop systems must support these increasing demands. Systems engineering is a multidisciplinary approach to develop balanced systems solutions in response to diverse stackeholder needs. Systems engineering includes the application of both management and technical processes to achieve this balance and mitigate risks that can impact the success of the project. The technical processes are applied to specify, design and verify the system to be build. Model-Based Systems Engineering (MBSE) applies systems modeling as part of these processes to support analysis, specification, design and verification of the system being developed.

A primary artifact of MBSE is a coherent model of the system being developped. A model is a representation of one or more concepts that may be realized in the physical world. It generally describes a domain of interest. A method is a set of related activities that implement one or more processes. A MBSE can be characterized as a method that implements all or part of the systems engineering process, and it produces a system model.

SysML [13] [20] is the new industry-standard language designed specifically to support MBSE. It a general-purpose graphical modeling language that supports the analysis, specification, design, verification and validation of complex systems. these systems may include hardware, software, data, personnel, procedures, facilities and other elements of man-made and natural systems.

Exemples of MBSE with SysML can be found in [11], [4], [16], [1], [15].

Références


