Integrated Modeling Proposal of Supervisory Control Theory and Model-Based System Engineering

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Abstract

The Supervisory Control Theory (SCT), firstly introduced by Ramadge and Wonham in 1987, is one of the most important paradigms of formal modeling, control synthesis and verification for Discrete Event System (DES). The large number of scientific contributions shows that SCT catches extensive academic interest and this theory has been proved to be applicable in various industrial domains such as manufacturing systems, embedded systems or energy systems, etc. With SCT, the requirements which are checked afterward in traditional engineering are used as input for generation of the design of the controller that is correct by construction. By the scientific achievements within the past several decades, the framework of SCT forms a systematically formal paradigm to synthesize controllers for DESs and a series of concepts and methods are proposed.

However, despite the academic achievements of SCT, there are still gaps between the theoretical development and applications of SCT in engineering practice. Firstly, there is a lack of interpretation between informal requirements and formal specifications in typical development process. Systems' requirements are usually written in an informal narrative since it generally means a greater understanding among the various stakeholders. On the other hand, formal models such as automaton have unambiguous semantic, which means a model cannot be understood in different ways. It is still difficult to link the formalization and informal narrative requirements. Secondly, as the formal model can only represent the behavior of system to be studied, it is difficult to describe the structure aspect, which includes both physic and logic. The gap between plants and physic components leads to the problem: the consistency between plants and physic components is unclear. Besides, the supervisor/controller may also be structured. Unfortunately, there is no model can be used to explicitly describe the details of the structure. The existing contributions focus on how to transform the supervisor to the software and hardware aspect of concrete controller is neglected. In fact, it leads to problems of controller implementation. In fact, these two situations are due to ambiguity for hardware and software and lack of the implementation models. The existing supervisory control architecture and implementation methods are not able to specify the link between the models of supervisor/controller and models of concrete controller, which is unacceptable in the engineering

context. Finally, the SCT does not provide the global modeling process from analyzing and decomposing the informal requirements to sub-systems to transform models to implementation.

The Model-Based System Engineering (MBSE) provides the possibility to deal with the limitations of SCT. MBSE is the actual state-of-the-art global design process in engineering practice. A variety of modeling languages are proposed by OMG for realizing the MBSE methods. Especially, SysML is one of the most important modeling languages, which provides nine kinds of diagrams to be used to describe different aspect of the system. The main objective of the work is to propose an integrated modeling framework for controller development by combining Supervisory Control Theory with Model-Based System Engineering to bridge the gaps formal approach and engineering process. In the proposed framework, different SysML diagrams are used to as complementary models, which present the indispensible views of the system to be studied in the global modeling process. The proposed framework focuses on the improvement of the traceability, consistency and reusability, compared with the conventional SCT-based modeling process.

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