DOCTORAL CANDIDATE: Muhammad Fadlisyah
DEGREE: Philosophiae Doctor
FACULTY: Faculty of Mathematics and Natural Sciences
DEPARTMENT: Department of Informatics
AREA OF EXPERTISE: Formal methods, physical systems
SUPERVISORS: Peter Olveczky, Erika Abraham, Olaf Owe
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DISSERTATION TITLE: A Rewriting-Logic-Based Approach for the Formal Modeling and Analysis of Interacting Hybrid Systems

This thesis is motivated by the lack of flexibility of existing hybrid system tools for dealing with complex physical systems. It is based on two challenges: (1) how to adapt and extend existing formal methods for hybrid systems to deal with complex dynamic behaviors; and (2) how to enhance Real-Time Maude, a rewriting-logic-based tool for the formal modeling, simulation, and analysis of real-time and hybrid systems, to support the application of the new method in practice. Regarding these challenges, this thesis aims at developing flexible hybrid systems techniques for the modeling and analysis of complex physical systems, which emphasize the following aspects: (1) formal basis, namely, by having formal semantics based on real-time rewrite theories; (2) practicality, namely, by implementing these techniques in Real-Time Maude; and (3) scalability, namely, being able to deal with large physical systems with complex behaviors. The contribution of this thesis can be summarized as follows: (1) developing modeling techniques that provide an object-oriented method for specifying complex physical systems with interacting components in a modular and compositional way, where the continuous behaviors of such systems can be defined at the class level, instead of having to redefine the entire continuous dynamics for each configuration of the physical system components; (2) developing techniques for executing such hybrid systems, by approximating continuous behaviors by discretizing time evolution with fixed or dynamic time increment by adapting numerical methods for ordinary differential equations; (3) building HI-Maude, a rewriting-logic-based language and analysis tool supporting the formal modeling and analysis of such interacting hybrid systems by extending Real-Time Maude to implement the above modeling and execution techniques; and (4) demonstrating the applicability of the new tool on a case study modeling and analyzing the human body thermoregulatory system in an extreme environment.