

## Research Article

# Model Based Control System Design Using SysML, Simulink, and Computer Algebra System

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The Systems Modeling Language (SysML) is a standard, general-purpose, modeling language for model-based systems engineering (MBSE). SysML supports the specification, analysis, and design of a broad range of complex systems such as control systems. The authors demonstrate how they can integrate a SysML modeling tool (IBM Rational Rhapsody) with a proprietary simulation tool (MathWorks Simulink) and a Computer Algebra System (CAS) to validate system specification. The integration with Simulink enables users to perform systems engineering process in a SysML model, while designing continuous control algorithms and plant behavior in Simulink, and to validate the behavior by simulating the overall composition in Simulink. The integration with a CAS enables the evaluation of mathematical constraints defined in SysML parametric diagrams. The authors also show the overall approach using a Dual Clutch Transmission (DCT) and a Cruise Control System as examples.

## 1. Introduction

The Systems Modeling Language (SysML) has been under development since 2001 [1] by the International Council of Systems Engineering (INCOSE) and the Object Management Group (OMG) organizations, as a standard modeling language for model-based systems engineering (MBSE). The need for a standard modeling language originates from the fact that interdisciplinary complex systems, which require high-quality efficient systems engineering activities, are being developed by different teams, sometimes across companies in different countries, using a variety of tools and methods.

SysML extends a subset of the Unified Modeling Language (UML) [2, 3] targeted mainly for software engineering. This acknowledges the need for continuity from systems engineering to software engineering in the development of software intensive systems.

SysML supports the specification, analysis, design, and verification of a broad range of complex systems such as control systems. Part of the control systems specification includes dynamic (time-dependent) continuous behavior of the control algorithms and the physical environment;

these systems interact with the plant. In addition, SysML introduces a new kind of diagram called a parametric diagram used to define mathematical relations among attributes of the system using equations and inequalities. It is possible to define dynamic behavior of the system using time derivative function [4]. Using differential equations allows one to fully specify dynamic behavior; however, they are inadequate to design the reactive and transformational behaviors of the designed system parts.

One of the most effective methods of verifying a system is simulation. To simulate a system that consists of hardware and software, we have to define both discrete-time behavior and continuous-time behavior. To simulate a combination of discrete-time and continuous-time elements, we have to use a simulation tool such as Simulink or Modelica [5]. Although a simulation tool is well suited for defining a detailed behavior of dynamic system, it is not well suited for conducting the overall systems engineering processes such as requirement analysis and architectural analysis. To develop a complex system, we have to perform systems engineering processes before defining detailed behavior. Various researchers proposed integration of a SysML tool with a simulation tool to

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addiction remains one of the most important public health problems in western societies and is a rising concern for developing nations Over the past 3 decades experimental research on the neurobiology and psychology of drug addiction has generated a torrent of exciting data from the molecular up to the behavioral levels As a result a new and pressing challenge for addiction research is to formulate a synthetic theoretical framework that goes well beyond mere scientific eclectism to deepen our understanding of drug addiction and to foster our capacity to prevent and to cure drug addiction Intrigued by the apparent irrational behavior of drug addicts researchers from a wide range of scientific disciplines have formulated a plethora of theoretical schemes over the years to understand addiction However most of these theories and models are qualitative in nature and are formulated using terms that are often ill defined As a result the empirical validity of these models has been difficult to test rigorously which has served to generate more controversy than clarity In this context as in other scientific fields mathematical and computational modeling should contribute to the development of more testable and rigorous models of addiction

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