

## Chapter 5

# A Multidimensional Approach for Concurrent Model–Driven Automation Engineering

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### ABSTRACT

*Automation engineering heavily relies on concurrent model-driven design activities across multiple disciplines. The customization and integration of domain-specific modeling languages and tools play an important role. This contribution introduces a conceptual framework for this purpose that combines the modeling standards of the Object Management Group (OMG) with precisely defined specification techniques based on metamodeling and graph grammars. The main focus is on the development of synchronization mechanisms between modeling tools and on the presentation of some extensions of the underlying graph grammar formalism motivated by its application to a real-world scenario. These techniques are presented by a case study about the application of graph grammars within automation engineering.*

### INTRODUCTION

Mechatronic engineering is about integration of different engineering disciplines, mainly mechanical engineering, electrical engineering, and

software engineering. Within the machine and plant engineering process, software engineering is part of automation engineering, which deals with configuration and programming of devices like programmable logic controllers (PLC), motion controllers, and human machine interface (HMI)

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panels. Additional minor engineering disciplines are pneumatic and hydraulic engineering. Each discipline follows its own design methodology and uses specific models. Within the system development process, the sub-processes of the mechatronic engineering disciplines run in parallel with their own design iterations and design workflows. Furthermore, each discipline has a set of mainstream design tools for different types of models, different design principles, and a way of thinking that has evolved over time, depending on the maturity of a specific discipline.

As a consequence, the development processes of automation engineering are – at least on a first glance – considerably more complex than the established development processes for the software engineering subdiscipline of automation engineering. Any attempt to apply the principles of model-driven development as originally defined by the Object Management Group under the trademark MDA (Model-Driven Architecture) (Object Management Group, 2009) is likely to fail for the following reasons: MDA puts its main focus on the development of a single sequence of models on different *levels of abstraction* such that models on a more concrete level are automatically derived from models on a more abstract level. Usually, models on three levels of abstraction or refinement are distinguished: Computation Independent Models (CIM), Platform Independent Models (PIM), and Platform Specific Models (PSM).

In contrast, *Concurrent Model-Driven Automation Engineering (CMDAE)* as developed by Siemens AG and TU Darmstadt relies on a multidimensional framework for model classification and manipulation purposes. The *CMDAE Hypercube* distinguishes five main model classification dimensions:

1. **Concurrent Engineering Disciplines**
2. **Metamodeling Layers**
3. **Domain Customization Steps**
4. **Abstraction Levels**
5. **Evolution Timeline**

The classification of a (meta-)model within these five dimensions clarifies its role in a mechatronic engineering project like the case study presented in the following section. Furthermore, the CMDAE hypercube simplifies the systematic study of all kinds of (meta-)model manipulation activities and their interdependencies in an organization. The adoption of a new modeling language version in one discipline may, for instance, require that (1) its relationships to modeling languages used in other disciplines has to be modified, (2) old models must be converted such that they are legal instances of the new language version, (3) language specializations (profiles) for different domains must be updated, and (4) language preserving transformations to higher/lower levels of abstractions have to be modified, too. Different subsets of these ranges of so-called *megamodeling* activities (Kurtev, Bézivin, Jouault, & Valduriez, 2006) are studied by many research groups around the world, but a common classification framework comparable with the CMDAE hypercube that covers all these activities was missing until now.

In the Section “Background” we discuss related work activities. Thereafter, in Section “The Running Example and the CMDAE Hypercube” we present a running example that is used for illustration purposes. In Section “The CMDAE Hypercube” we describe the CMDAE hypercube and its dimensions in more detail. Section “The Metamodeling Pyramid (Dimension M)” and “Collaboration across Engineering Disciplines (Dimension C)” then focus on the hypercube dimensions (M) and (C) and present a number of extensions of our graph-grammar-based model engineering approach that have been developed in the context a joint research project between Siemens AG and Technische Universität Darmstadt. Section “Application and evaluation of CMDAE concepts” afterwards sketches how the first version of a CMDAE prototype, which supports concurrent model-driven mechatronic engineering activities, has been developed using the meta-case tool MOFLON (Amelunxen, Königs, Röttschke,

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