

DOCTORAL CANDIDATE: Razieh Behjati Ardakani
DEGREE: Philosophiae Doctor
FACULTY: Faculty of Mathematics and Natural Sciences
DEPARTMENT: Department of Informatics
AREA OF EXPERTISE: Software Engineering
SUPERVISORS: Lionel Briand, Shiva Nejati, Tao Yue
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DISSERTATION TITLE: *A Model-Based Approach to the Software
Configuration of Integrated Control Systems*

Modern society is increasingly dependent on integrated control systems. These systems are large-scale, highly-hierarchical, heterogeneous systems-of-systems, where software and hardware are integrated to control and monitor physical devices and processes and to ensure safety. Examples of such systems include oil and gas production platforms, industrial robots, and automotive systems.

To achieve higher quality and to reduce the overall engineering effort and production costs, many organizations in the integrated control systems domain resort to various reuse strategies. In particular, product-line engineering approaches have been extensively used to develop the software embedded in integrated control systems. Product development, in this context, is done through configuration, which is the process of selecting and customizing reusable components according to the specific needs of a particular product. Due to historical, managerial, and technical reasons, software configuration in the integrated control systems domain is largely manual and therefore, costly and error-prone.

In this thesis, we have identified the major causes of configuration problems and provided a solution to effectively address them. Our configuration solution is aimed at enhancing productivity of the configuration process and improving the reliability of the configured products. To that end, we introduce three main functionalities in our approach. First, we reduce the configuration effort by automatically making some of the configuration decisions. Second, our approach reduces the complexity of manual decision making by interactively guiding engineers throughout the configuration process. Third, our approach reduces the likelihood of human errors during configuration by instantly validating user-provided configuration decisions.

We rely on models of product family architectures, and use constraint satisfaction techniques over finite domains to implement the aforementioned functionalities. Product family models serve as a basis for inferring values, providing guidance, and validating user decisions. Constraint satisfaction techniques are, on the other hand, applied to analyze the models and extract the desired information.

As a major component of this thesis, we have proposed a modeling methodology, named SimPL, which helps create concise architecture-level models of product families in the integrated control systems domain. The SimPL methodology is particularly developed to enable the creation of product family models that can be used as a basis for automated configuration described above.

In order to further help reduce configuration effort, as part of this thesis, we proposed a similarity-based approach to the automated reuse of configuration decisions. The idea is that structural similarities can be modeled and used to trigger the automated decision-making capability of our solution to automatically make a greater portion of the configuration decisions. Due to the large degree of similarity within the internal structures of integrated control systems, this approach demonstrates a promising solution and our results show that it can save more than 60% of the configuration effort in our context.

The configuration solution has been evaluated on industrial case studies using a prototype configuration tool that we developed. Results of our evaluation show that our approach can guarantee the reliability of software products, while reducing the configuration effort.