Progress and Challenges in Product Configuration Systems Development

Dietmar Jannach, TU Dortmund, Germany, IJCAI 2011 Configuration Workshop Co-Chair
dietmar.jannach@tu-dortmund.de

I. Configuration Systems

Mass customization and configure-to-order production are modern business strategies in which the goods and services offered by a company are tailored and individualized according to the specific needs and preferences of the customer. The classical examples of such configurable products include cars, personal computers, and various types of comparably complex technical devices; today, however, you can also create your custom muesli, skateboard, or travel package over the Web.

Mass customization and configure-to-order are based on the idea that the final customer product can be assembled and configured based on a predefined set of components, to keep the individualization costs and the corresponding sales prices low. This contrasts with other strategies such as engineer-to-order, in which customer-individual goods are manufactured,

Fig. 1. Barcelona impressions

Product configuration systems (configurators) are software applications that play a central role in such business approaches, in particular because in most cases the individual components cannot be assembled to the final customer product in an arbitrary way. Typically, the configuration process is governed by a set of constraints. In the car domain, such a constraint could for example be that one certain type of engine is not available with an automatic gear box. The reason for the existence of a constraint can both be technical (e.g., because of mechanical incompatibilities) or marketing-related (e.g., based on pricing strategies).

The tasks of a configuration system usually include the interactive acquisition of the user preferences, checking for constraint violations, the automatic completion of partial configurations, the generation of sales quotes (in case the configurator is used as a front-end sales tool) or a bill-of-materials (if it is used for back-office automation).

Beside the problem of the seamless integration of configurator solutions into a company's existing software infrastructure or ERP system, the development of the above-mentioned core configurator functionalities is not a trivial task for various reasons. One of the core problems is that of *knowledge representation*, that is, the question of how to encode the given constraints in the system. Note that the corresponding knowledge bases can be huge and comprise hundreds or even thousands of rules. Beside that, they are also subject to frequent changes in particular in technical domains. Another issue is that of *computational complexity*. In the end, configurations can consist of thousands of components, for example, in the telecommunications domain. Finally, there is also the aspect of *user interaction*. Note that interactive elicitation of the requirements is not a one-shot process, but often requires multiple interaction loops, e.g., for situations in which constraints are violated and the user has to revise some of the choices.

Due to their inherent complexity, configuration problems have always been in the focus of researchers in different areas of Computer Science, and in particular of Artificial Intelligence (AI) researchers, for the last 30 years. In fact, one of the earliest successfully applied rule-based expert systems was a configurator for computer systems.

Since these early rule-based years, progress was made with respect to various aspects of the development of configuration systems. Regarding modeling and knowledge representation, a number of languages were used to represent the configuration knowledge. Some of the approaches used first order logic or its decidable subsets such as constraints, description logic, or answer set programming. Others are based on graphical modeling languages. Reasoning was based on logical inference, case-based reasoning, different constraint satisfaction schemes, resource-based reasoning as well as interactive propose-and-revise approaches. With respect to user interaction, proposals have, for example, been made toward the personalization of the user interface, the dynamic pre-selection of input values or strategies to recover from situations when the user requirements cannot be satisfied. Beside these core issues in configurator development, researchers also put forward ideas toward intelligent debugging support for the knowledge bases, algorithms for distributed configuration problem solving as well as approaches addressing the problem of re-configuring an existing system.

In general, research in configuration systems is application-oriented and focusing on the development of generalizable solutions for practical problems in industry. In fact, we can observe that several ideas developed in the research community in the last decade made their way into industrial practice and that configuration is among those fields where AI technology has been successfully integrated into software products and applied in commercial settings.

II. The Configuration Workshop at IJCAI'11

The International Joint Conference on Artificial Intelligence (IJCAI), which took place in Barcelona in July 2011, featured a one day workshop on configuration. After a AAAI Fall symposium in 1996, this year's workshop was already the thirteenth in a series of successful configuration workshops held at major international AI events such as IJCAI, AAAI or ECAI since its first edition in 1999.

Since the inception of the workshop series, strong and continuing interest from industry can be observed including tool providers such as ILOG (now IBM) or Tacton AB, ERP vendors like SAP and Oracle as well as large corporations (like Siemens or ABB) but also smaller configurator companies.

This year's workshop featured two invited speakers and a scientific program consisting of four long paper and three short paper presentations. In the opening keynote talk, Fabrizio Salvador from the Instituto de Empresa Business School in Madrid looked at configuration systems from the business perspective. In particular, he emphasized the importance of the effective management of information on feasible product configurations to achieve higher responsiveness towards the customer. As an additional factor, he discussed not yet fully tapped potentials of learning from past configurations.

Learning from past configurations – although with a different purpose – was also the main idea of the paper "Incremental prediction of configurator input values based on association rules" presented in the subsequent technical sessions. In this work, the goal was to make the interaction with a configuration tool more convenient for the end user by dynamically pre-selecting appropriate input values and thereby reducing the interaction efforts.

The main focus of this year's workshop, however, was on modeling. The presented works at the workshop included (1) a new graphical modeling approach which covers not only the configurable artefact but also the production process; (2) an integrated method to model the variability in heterogenous product families based on different *views*; (3) a best-practice modeling guideline for knowledge engineers involved in configuration development; and (4) a new modeling language, which can be used not only for configuration modeling but also for re-configuration and simulation purposes.

The second key topic of the 2011 workshop was on knowledge representation and reasoning (KRR). In the second keynote, Gerhard Friedrich from the Alpen-Adria University Klagenfurt, Austria, first reviewed key milestones with respect to KRR in the configuration domain. He then illustrated current challenges and solutions with the help of hard real-world configuration problem and presented results of a comparison of various KRR frameworks including Answer Set Programming (ASP). The results demonstrated the significant progress that has been made in the area in the last few years so that these KRR frameworks can nowadays be applied to solve practically relevant problems.

Answer Set Programming was also the basis for a new reconfiguration presented in another technical paper in the workshop. In this work, the authors demonstrated how the configuration and reconfiguration problem can be encoded in the ASP framework and present experimental results which indicate the feasibility of the approach for practical applications.

An alternative problem encoding was finally presented in the paper "Enumeration of valid partial configurations", where the authors show how incremental SAT solvers can be used for online computation of partial configurations. These partial configurations are then used to suggest possible assignments, thus reducing the information load and improving the quality of decisions made by a user while configuring a product.

Overall, the workshop highlighted that significant advances have been made in the configuration area over the last years with respect to configuration modeling, knowledge representation and reasoning, and in particular that modern AI technology is more and more on the way to be usable nearly "off-the-shelf" for practical applications.

Despite these advances, many opportunities for future research remain in the configuration domain. For example, it would be interesting to see how the developed techniques can be applied beyond classical hardware configuration problems, e.g., for software and service configuration or model transformation. In addition, also different questions of knowledge acquisition and how to better integrate data from existing sources such as ERP or product data management systems with the configurator are still open. Finally, user interface issues were historically slightly underrepresented in this research community. Given that more and more products for the end-customer can be individualized over the Web, more focus has to be put on techniques for building adequate configurator user interfaces including aspects of "intelligent" customer guidance or 3D-visualization.

The papers of the IJCAI 2011 Workshop on Configuration can be downloaded at http://ceur-ws.org/Vol-755.

Fig. 2. Barcelona impressions

Dietmar Jannach is a professor in Computer Science at TU Dortmund, Germany and chair of the e-Services Research Group. His main research interests lie in the application of artificial intelligence and knowledge-based systems technology to real-world problems in particular in e-business environments. He has authored numerous papers on intelligent sales support systems such as recommender systems or product configurators. Dietmar Jannach was also one of the co-founders of ConfigWorks GmbH, a company focusing on next-generation interactive recommendation and advisory systems. He was a co-chair and organizer of the configuration workshop and the workshop on "Intelligent Techniques for Web Personalization" at IJCAI'11 and also gave a tutorial on Recommender Systems.