Semantic Reasoning for Automated Factory Planning

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Abstract: This article outlines the novel directions talk on semantic reasoning for decision-making support and automation in the domains of production engineering. With the use case of factory planning, the potentials and challenges are demonstrated on an application example in capacity planning. On the basis of a factory information model, a calculation model was defined to deduce planning results automatically. Recommendations for future research topics are given in the conclusions.

Keywords: Digital Factory · Production Design · Information Modeling · Ontologies.

1 Modeling Production Systems for Decision-Making Support

Resulting from today's dynamic market environment, the changing requirements to production systems justify continuous planning efforts to maintain cost-effective production. These planning efforts in designing and dimensioning the production system are associated to the task of factory planning. State-of-the-art planning approaches are characterized by modularity and project-specific configuration [SKW10]. Experts are provided with digital tools and applications to support in planning tasks. However, available integrated solutions limit adaption to project-specific requirements and raise the problem of interoperability by lacking interfaces for information exchange across applications and databases [DRA18].

Recent research investigates semantic information modeling for management of factory data to represent production systems virtually [Bü16]. Ontology-based information modeling allows connecting heterogeneous data sources in a data model that offers machine-interpretable data for processing in subsequent use cases. With such basis, implicit information can be logically deduced to support decision-making in factory planning tasks. Planning scenarios can be validated by checking for inconsistencies, e.g., as demonstrated in MEP design (mechanical, electrical and plumbing aspects of the production facility) [Bu21]. Another example of recalculating planning results will be given in the following section. Thereby, factory planning will serve as a use case to demonstrate the potentials of extending the modeling of production systems by semantic reasoning. Particular focus is set on how decision-making can be supported for automation in production engineering. As a result, currently used planning tools such as simulation software can be advanced in their functionality. Additionally, the approach can be applied

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to further use cases in related domains of production engineering, e.g. production planning, that are also profiting from automation support in decision-making.

2 Application Example in Capacity Planning

Capacity planning is a typical task of factory planning by determining the required number of production resources. By comparing capacity demand of the products to be manufactured with the supply of capacity through the production resources, the capacity utilization is calculated and then considered in dimensioning the production system.

Following the ontology engineering methodology [SSS09], application-specific requirements were collected before conceptualizing and modeling an ontology for the described task of capacity planning. It was implemented as a conceptual factory information model in the ontology editor Protégé. In the following step, concrete factory information from an industrial factory planning project was imported. The source data in tabular format from an Excel file was mapped to the ontology with the plug-in Cellfie. Finally, the semantic web rule language (SWRL) was used to define a generic calculation model with rules for semantic reasoning. For example, capacity utilization for specific production resources is deduced from available factory information for different planning scenarios, as shown in Fig. 1.

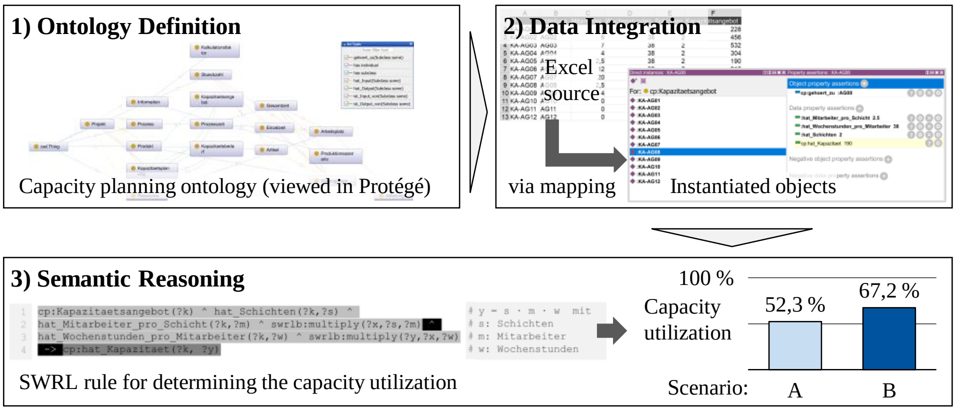

Fig. 1: Applied procedure for semantic reasoning of capacity utilization in capacity planning.

Eventually, the calculation results are automatically added to the information model and is available for further planning processes. Recalculations are automatically performed with updates of factory information. Similarly, factory information from different projects can also be processed, as the calculation model is defined generically.

A major challenge was found in the notably long processing times for reasoning (e.g., 7,7 s calculation time from 526 instantiated objects for a part of an industrial factory planning project), even rendering some proposed calculation rules unusable. Furthermore, the applied software tools are often not accessible to end users. The definition of the calculation rules also proves unrealistic for practical factory planning projects as their setup exceeds acceptable efforts for the average factory planner. However, this drawback can be countered by pre-defining the calculation rules for the conditions typically encountered in capacity planning tasks. Otherwise, integration of semantic reasoning into planning software could provide end users with improved calculation rule formulation in user interfaces.

3 Conclusions and Future Research

The implementation of semantic reasoning to support planning experts in capacity planning shows promising potentials for automation in the use case of factory planning. With semantic information models becoming increasingly available across production engineering, domain experts are encouraged to exploit them for support and automation of decision-making. To implement further identified use cases, their underlying decision-making processes need to be specified systematically. From the perspective of software development, end-user-accessible interfaces need to be designed. Equally important is the realization of methods for faster semantic reasoning, e.g., by using semantically-enriched but local data bases, as outlined in [BS16], or with ontology-oriented programming.

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