Improving industrial optimization with Semantic Web technologies

Benjamin Mörzinger[1], Marta Sabou[2], Fajar J. Ekaputra[2], and Nikolaus Sindelar[1]

[1] Institute of Production Engineering and Laser Technology - TU Wien, Getreidemarkt 9, 1060 Vienna, Austria
[2] Institute of Information Systems Engineering - TU Wien, Favoritenstrasse 9-11, 1040 Vienna, Austria

Abstract. Time-series based simulations of industrial processes are instrumental to optimizing a variety of industrial settings. In this paper, we describe a use case, developed together with Infineon Technologies Austria AG. Monitoring data stored in relational databases was used to build process models of industrial chillers. Optimization algorithms were then applied to find optimal strategies for operating the chillers. Even though the results from this approach were convincing, the access to the necessary data was a labor-intensive and error-prone task. Therefore, in this paper, we investigate how Semantic Web technologies can help to improve data access for time-series data and under which circumstances they would be helpful for the domain experts performing the simulation.

Keywords: simulation · manufacturing · ontology-based data access

1 Introduction

This use case is an actual semiconductor plant operated by Infineon Technologies Austria AG in Villach, Austria. In total, twelve chillers with electrical power input rates between 300 and 500kW were investigated. The optimization of the operation schedule of these chillers was the goal of our use case. Simulation models were created using historic monitoring data. The resulting simulation model was combined with an optimization module. Accessing the data necessary to create those models is an error prone and tedious task. Therefore, we propose the extension of a simulation software with Semantic Web technologies which allows the definition of semantic mappings to the input sources of time-series data in line with ontology-based data access (OBDA) principles.

We developed a Semantic Web prototype in the context of a concrete use case from industry. This use case originally was defined in the research project Balanced Manufacturing (BaMa) [4].

2 Semantic Web technologies for data access

Recent studies [1] show the emerging trend of using Semantic Web technologies in industrial use cases. The use of Semantic Web technologies for industrial simulation mostly focuses on employing an ontology as a common data model for integrating data from heterogeneous data sources for simulation purposes, such as the Virtual Factory Framework [7]. A different use of ontologies is proposed by Novak and Sindelar [6,5], where they are using ontologies to suggest and reason simulation model building blocks for simulation model development. These approaches, however, are developed based on the traditional ETL approach, which restricts the scalability of the system due to the limitation of RDF Graph storage capabilities.

OBDA systems were developed in the course of the EU funded Optique project[3]. One of the results is the Ontop framework which we also make use of in this work [2,3].

3 Facilitating Access to Simulation Data with Semantic Web Technologies

In the given application area, the data access tasks vary and are hardly ever repeatedly executed. Therefore providing predefined SQL queries is not a suitable solution as these would have to be adapted quite often.

We applied a simplified version of existing ontology development methods in order to develop the ontologies for our OBDA prototype. The primary goal was to evaluate the general technical applicability and motivate further development. The development process started with example expert questions. These, and other similar, questions had to be answered throughout the model parametrization process. Some example questions are:

- Which chillers are located in building XY?
- Show all chillers located in country YW.
- Which chillers are connected with recooling plant YZ?

Based on those questions, two ontologies were created: the *Top Level Ontology* and the *Chiller Ontology*. The decision to create two rather than a single ontology was made in order to illustrate that it is possible to combine different conceptualizations of a domain in one prototype tool.

The Top Level ontology, depicted in Figure 1a, represents the main domain concepts and their relations. This ontology could be used in order to combine different, more specialized ontologies, such as the one depicted in Figure 1b. The concept *Machine* from the top-level ontology is further specialized in the Chiller ontology in terms of various chiller types. A different way to expand the ontology might be to describe the *Building* domain in more detail. Such extensions, however, were not in the scope of the prototype.

We used Ontop's Protégé plugin to implement our prototype. This plugin aids the mapping process. A mapping combines results from SQL queries with ontology elements such as concepts and predicates. This can be seen as a virtual T-box. The defined mappings are then used to translate SPARQL queries

[3] http://optique-project.eu/

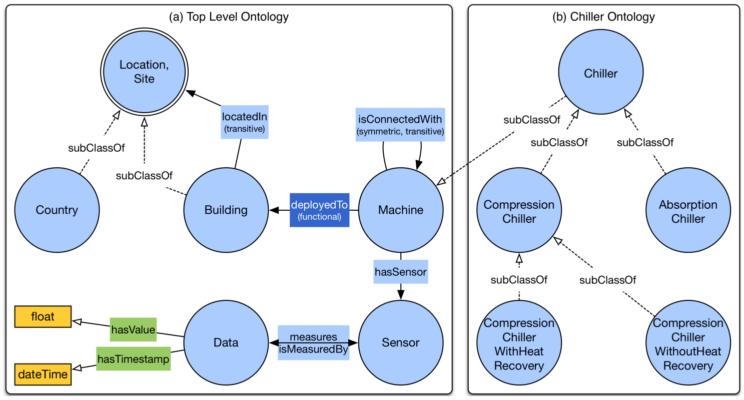

Fig. 1: Top Level and Chiller Ontologies

Listing 1.1: query

```
SELECT DISTINCT ?Machine ?SensorName ?Data
    WHERE       {
        ?Machine :hasSensor ?Sensor .
        ?Machine a ch:Chiller .
        ?Machine :isConnectedWith ?otherMachine.
        ?otherMachine :Mname ?otherMachineName .
        ?Sensor :measures ?Data.
        ?Sensor :name ?SensorName .
        FILTER (?otherMachineName="RKW3")
        }
```

(constructed with terms from the ontology) into SQL queries (executed on the underlying databases).

An example query can be seen in (Listing 1.1), some technological capabilities of the Semantic Web are used to identify sensors based on knowledge such as machine types and machine connections. This information, without the use of the Semantic Web, would have to be extracted from factory plans or wiring diagrams. Necessary meta-information, which is stored in the database, can be used directly by domain experts for their queries. In the given example, only sensors generating data from machines which are connected to other machines are returned. Then, the results are filtered so that only those where machine 2 was a specific kind of recooling plant (identified via its name) are returned to the user. Another aspect that is covered in this example is reasoning. Only the predicate *isMeasuredBy* was explicitly mapped to data from the underlying dataset. Nevertheless, the query makes use of the *measures* predicate (the inverse of *isMeasuredBy*) which is possible thanks to the reasoner being aware of OWL semantics.

4 User Feedback

The presented prototype was shown to project partners familiar with the use case. Then, user interviews were conducted. Based on the results we are confident, that the Semantic Web can improve data access for domain experts and therefore improve adaption of simulation-based approaches to optimization tasks. The general approach is seen positively by the involved stakeholders. User interaction and implementation with legacy systems, however, need to be addressed in order to make the system actually useful in a production environment.

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[4] `http://bama.ift.tuwien.ac.at/`