Towards Semantic Integration of Bosch Manufacturing Data

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Data Integration Challenge for Industry 4.0. Industry 4.0 (I4.0) is a global trend in manufacturing aiming at plants with fully computerized and automated production processes. In these plants, production assets, such as assembly lines and manufacturing robots, are heavily equipped with sensors that report various characteristics of assets including temperature, state, and errors in operation. Sensor data collected from assets can be integrated with the master data describing more static information of assets such as engineering specifications, input/output, as well as with the descriptions of manufacturing processes at the plant, and then used for real time asset monitoring, diagnostics, and control. The latter tasks are in the heart of I4.0 and they are challenging due to the complexity of the required underlying data integration over heterogeneous information of temporal nature that has high volume and velocity [4]. This integration challenge has attracted a considerable attention in both academia and industry, where the notable industrial solutions include Siemens Mindsphere and ABB Ability.

Bosch has more than 400K employees worldwide and its manufacturing targets a wide range of markets including automobile industry, consumer goods, energy, building technology. According to a Bosch internal study at a dozen of production plants, the current estimated cost for data and machine integration tasks for I4.0 applications at Bosch is around 90M EUR. To facilitate this I40 shift at its factories Bosch develops the Nexeed platform. It will in particular leverage the Digital Twins technology for modeling industrial assets, semantics for integration of data across assets, and AI to empower diagnostic and analytic tasks. In order to exemplify how semantics facilitates data integration at Bosch, we next briefly describe a real-world use-case from a Bosch Salzgitter factory where we work on a development of a semantic solution.

Bosch Use-Case: Integration of Data from Manufacturing of Electronic Panels. Bosch is a leading producer of sensors and related chips. For example, Bosch has a chip factory in the area of Salzgitter city in Germany that in particular produces electronic panels, see top-left part of Figure 1. Production of these panels involves placement and soldering of electronic components on Print Circuit Boards, see bottom-left part of Figure 1. This involves several machines including Surface Mount Devices (SMD) that place components on boards, electric ovens that solder components to the boards, and Solder Joint Inspection (SJI) devices that detect flaws in joints and misplacement of the components. All these machines are equipped with sensors and produce data of various complexity and heterogeneity. E.g., SMD machines usually use multiple (vacuum) nozzles to pick (possibly multiple) components for placement and this triggers a sequence of picking and placing actions and generation of the corresponding temporal data. Then, SMD machines can change nozzles and manufacture panels at a very high frequency: a Panasonic SMD machine CM602 can place up to 100,000 components per hour. Thus, sensors of an SMD machine produce large volumes of various data during a shift: sequencing of actions, changes in nozzles, etc.

From Digital Twins to Semantics in Bosch Data Integration. In order to unify and integrate data from individual machines involved in panel manufacturing at Reutlin-

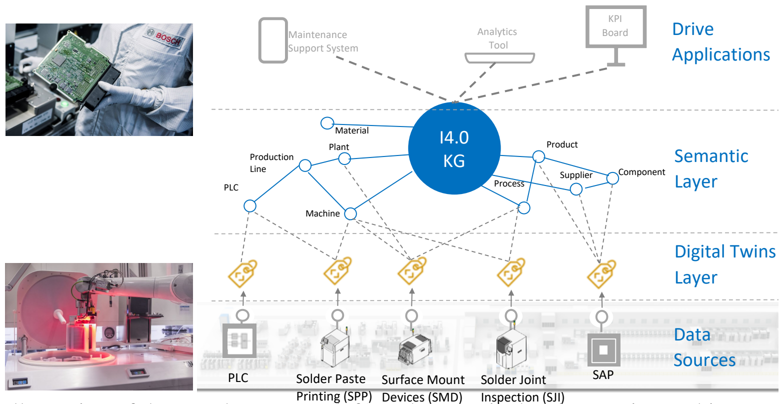

Fig. 1. Illustration of the Bosch use case (left) and semantic data integration architecture (right).

gen and other factories Bosch offers an in-house Digital Twins solution. Bosch Digital Twins allow to model manufacturing equipment via so-called Aspect Models that allow to describe each machine by declaring the kind and format of the data they can report. In Figure 1, right, there are yellow Aspect Models on top of SMD, SJI and other machines. Aspect models can then be directly connected to applications for monitoring and analytics, or further integrated via a semantic layer, see Figure 1, right.

In our work we developed a semantic layer on top of the digital twins of the Reutlingen factory. This layer allows to exhibit streaming data from manufacturing machines in a unified fashion. In addition, it combines it with other kinds of data, e.g., master data from SAP, to describe relationships between individual machines, and to offer data to applications in a more abstract fashion (cf. Figure 1, right). We achieve this by leveraging the ontology-based data access (OBDA) approach that has recently been successfully used in several companies [1, 4, 2, 5, 3]. At this stage of the project we developed an ontology with hundreds of classes and properties that captures the domain of chip manufacturing and unifies Reutlingen machines and manufactoring processes. We then developed a set of declarative mappings to relate this ontology to dozens of Reutlingen digital twins. In order to show the benefits of the OBDA technology, we rely on several third party systems including Ontop and Sansa.

Outlook. A significant progress towards realizing the OBDA solutions within electronic panel manufacturing at Bosch has been already done: our system is up and running. Nevertheless, in the next years we plan to further develop and integrate our solution in Reutlingen and possibly other factories. In particular, we plan to focus on several important issues: effective handling of complex temporal queries, analytical tools for temporal data, scalable distributed query processing as well as support for semi-automatic ontology and mapping construction.

References

1. Elmer, S., Jrad, F., Liebig, T., ul Mehdi, A., Opitz, M., Stauß, T., Weidig, D.: Ontologies and reasoning to capture product complexity in automation industry. In: ISWC P & D (2017)
2. Kharlamov, E., Hovland, D., Skjæveland, M.G., Bilidas, D., Jiménez-Ruiz, E., Xiao, G., Soylu, A., et al: Ontology Based Data Access in Statoil. J. Web Semant. **44**, 3–36 (2017)
3. Kharlamov, E., Kotidis, Y., Mailis, T., Neuenstadt, C., Nikolaou, C., Özçep, Ö.L., Svingos, C., et al: An ontology-mediated analytics-aware approach to support monitoring and diagnostics of static and streaming data. J. Web Semant. **56**, 30–55 (2019)
4. Kharlamov, E., Mailis, T., Mehdi, G., Neuenstadt, C., Özçep, Ö.L., Roshchin, M., et al: Semantic Access to Streaming and Static Data at Siemens. J. Web Semant. **44**, 54–74 (2017)
5. Kharlamov, E., Mehdi, G., Savkovic, O., Xiao, G., Kalayci, E.G., Roshchin, M.: Semantically-enhanced rule-based diagnostics for industrial internet of things: The SDRL language and case study for siemens trains and turbines. J. Web Semant. **56**, 11–29 (2019)