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# The Data Value Quest: A Holistic Semantic Approach at Bosch

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**Introduction.** Modern industry witnesses a fast growth in volume and complexity of heterogeneous manufacturing (big) data [1, 2] thanks to the technological advances of Industry 4.0 [3, 1], including development in perception, communication, processing, and actuation. Data has become the new oil for industries<sup>8</sup>. However, despite the effort and time invested in the data business, there still exists a big room for improvement in exploiting the value of data. In particular, data is still often scattered and stored in silos affecting its usage [4]; a lot of data generated by sensors is not used in applications; companies possess precious data but do not have a trustworthy scheme to share its value; etc. There are certainly many ways to address these issues. In this paper we discuss the dimension of meaning in data and how we address it at Bosch (Fig. 1) in a holistic semantic-fication fashion that bestows data with meanings which has always been important for humans to perceive, comprehend, reason, and produce. We believe the emphasis, the clarification, and the promotion of the eminent and profound roles of semantic technologies in the industry should lead to considerable opportunities for advances in technology, growth of profitability, and paradigm change in the industrial practice.

## Holistic Semantic-fication at Bosch.

- **Data collection.** Semantic-fication begins with data collection [5]. During which, vast amounts of heterogeneous data with multi-faceted variety in locations, formats, physical equipment, customisation, etc. are annotated with precise and uniform meta-data, which sets the first corner stone for many activities that are based on the collected data.
- **Data understanding.** In big manufacturing companies like Bosch, data science projects are typically multi-disciplinary teamwork where experts with asymmetric knowledge backgrounds (e.g., engineers, equipment experts,

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<sup>8</sup> <https://blog.s4rb.com/data-is-the-oil-of-the-21st-century>

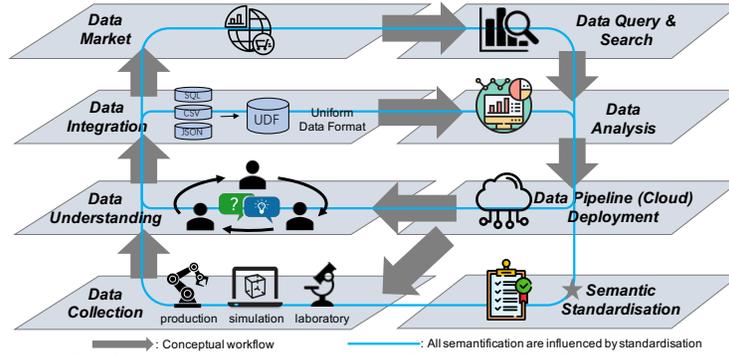


Fig. 1. An overview of our holistic semantification approach

measurement experts, data managers, data scientists, managers) need to talk to each other, to gain a mutual understanding of the process, data, solution, infrastructure, strategic interests, etc [6]. These experts with distinct backgrounds speak different technical or management languages, which tends to lead to error-prone and time-consuming communication. Thanks to their conciseness and unambiguity, semantic models play an essential role here, serving as the “lingua franca” between the experts speaking different languages [7, 8].

- **Data integration.** We rely on ontologies and knowledge graphs (KG) to annotate heterogeneous welding manufacturing data from Bosch and its partners with unified vocabularies. Then, enhanced by the ontology reshaping method developed in Bosch [9, 10], we transform them into uniform data formats/databases that allow uniform access, interoperability, and unified interpretation.
- **Data market.** Bosch participates in a digital open marketplace ecosystem [11], which provides a sustainable approach to connect the data providers and the data consumers to help to connect Bosch and its partners. The ontologies and KGs make the data easier to reach from and by Bosch’s production units, suppliers, and customers.
- **Data query & search.** Data like XML files, KGs [12, 13] provide an efficient foundation for querying information of interest via clearly defined formats. SPARQL queries or keywords are used to query data [14–17] for inspection, information summary, and diagnostics. Data search outputs datasets, databases, or snippets of datasets [18–21] and relies on the metadata-based query, KG summarisation, natural language-based search [22], or even the content-based search, which Bosch is researching on.
- **AI and Data analysis.** Here Bosch relies on semantics in diversified ways like scaling usability of data analysis (typically machine learning (ML)-based) pipelines [23] with user interface, which improves the adoption of ML [24], (semi-)automate the generation of ML pipelines with ontologies, templates, and reasoning [25] incorporating domain knowledge via annotation and KG embeddings, etc.
- **Data pipeline deployment (scalability).** Bosch develops semantic abstraction of cloud resources for computing, storage, and networking that

facilitate the deployment of distributed ML pipelines, thus scaling the data analysis onto the big data level [26, 27]. Adaptive rule-based reasoners help to automate the configuration of resource allocation.

- **Semantic standardisation.** Now Bosch participates in the endeavour [28] working towards addressing the long call of the standardisation of semantic artefacts [29], infrastructure, and best practice via e.g. aligning to ISO standards, existing vocabularies, achieving common agreement.

**Conclusion.** This work gives a panorama view of semantic technologies in the data business at Bosch that is in development. We aim at advancing the exploitation of the values of data in the manufacturing industry. We envision semantic technologies continuing to be one of the keys to unlocking the potential of the values of data.

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