Towards FAIR Data Principles at Bosch

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OntoCommons Workshop
Towards Materials and Manufacturing Commons - the enablers Digital Marketplaces, FAIR Principles and Ontologies

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We want our products and solutions to spark enthusiasm, enhance the quality of people’s lives, and help conserve natural resources.

In short, we aim to create technology

Invented for life
Who we are
Our company in figures

In 2022

88.4 billion euros sales revenue
3.7 billion euros EBIT from operations
420,300 Bosch associates worldwide at year-end (approx.)
440 subsidiaries and regional companies in more than 60 countries
Where we want to go
Where we want to go

Industry 4.0

Bosch is a leading provider of innovative Industry 4.0 technologies which enhance teamwork between people and machines. Thanks to machines and processes that feature AI-driven connectivity, Bosch plants take automation to a new level.
Traditional approach for Data usage

Application centric approach

Applications

Data Sources

ERP
MES
Production
Vehicle
Claims
Engineering
Traditional approach for Data usage

Challenges

Non existing work towards standardization, reusability and scalability

Semantic explicit leading to different interpretations and usage of data

Non reusable applications/data models

Semantic Interoperability Conflicts

Data Silos – Yet another excel sheet, table or local data dump

Very poor data quality

Data Engineers, Scientists, have to do the same work over and over again

Time and money wasted
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Data Centric with Semantics (Meaning) at its Core

Data enables the business
Semantics enable the data

“Semantic work on data will be the future.”
Dr. Stefan Hartung
Chairman of the board of management
Where we want to go
Generate wisdom based on domain-specific knowledge

Data
- availability & access

Information
- contextualized
  - information, insights
- data interpretation
  - organized, structured, categorized, calculated
  - individual facts, figures, signals, measurements

Knowledge
- understanding, integration, applied, actionable, accumulated, principles, patterns
  - know-how, concept, synthetized, compared, discussed

Wisdom
  - We can generate wisdom based on our domain-specific knowledge

Example: Process optimization
- We have optimized process X in plant P to reduce errors of product Y
- Process X in plant P is core for manufacturing product Y
- Process X in plant P for product Y has produced more than 50 errors
- "dispensing process", "plantP1", "pump1", error_code: "wrong dispensing"
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Semantic data integration and harmonization using Knowledge Graphs (KGs)

Apps

Digital Twin

Data

Fabric & Data

Mesh

Data Sources

ERP

MES

Production

Vehicle

Claims

Engineering

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Knowledge Graph-based Approach
Semantic data integration and harmonization using KGs

Apps

Data

Fabric & Data Mesh

Data Sources

ERP
MES
Production
Vehicle
Claims
Engineering

Digital Twin

Core Information Model for Manufacturing

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Industry 4.0 Core Information Model for Manufacturing Ontologies

- A set of interconnected ontologies for dealing with core concepts in the Manufacturing domain
- Based on IEC 62264 standard
- White paper and ontologies published in the context of Eclipse Foundation
- Used by Bosch in several use cases as well as by other manufacturing companies
Industry 4.0 Core Information Model for Manufacturing

Equipment (logical) Ontology

Physical Asset Ontology

Legend

- **Class**
- **SubClass**
- **Relationship**

**Class:**
- Plant
- Logical Site
- Area
- Work Center
- Work Unit
- Pool
- Line
- Station
- WorkCell
- Machine Component
- Machine Tool
- Building
- Asset
- Machine
- Location
- Site

**Relationship:**
- isLocatedAt
- isPhysicallyAt
- implementedBy
Industry 4.0 Core Information Model for Manufacturing

Product Segment Ontology

- Process Segment: Drill shaft holes
  - Equipment Specification: Equipment Aluminium Cast
  - Parameter Specification: Hole diameter 8mm, Holes length 12mm
  - Material Specification: Material Transmission Housing (mat.no.: 1111222333)

- Product Segment: Housing front side
  - hasEquipmentSpecification
  - hasParameterSpecification: Hole diameter 7,95 mm, Holes length 12,05 mm
  - hasMaterialSpecification

- Product: Transmission Housing1
  - implements ProcessSegment
  - isFollowedBy Segment Result
  - hasSegmentResult
  - hasParameterValue: Hole diameter 7,95 mm, Holes length 12,05 mm
Different levels of ontologies
Core and domain ontologies, data catalog

- Core Ontologies are defined to represent central and cross-domain concepts inside the organization
- Domain ontologies are focused on specific domains, e.g., manufacturing with the CIMM
- Use case and application ontologies typical extend Domain ones and further specify concepts on demand
- All levels are inter-connected and make use of the Data Glossary
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Use Case: Manufacturability Analysis

- Typical scenario for finding lines capable to manufacture a certain product
- Product and the Manufacturer Engineer collect data for answering the question whether a certain product can be manufactured in a production line
- Semantic interoperability conflicts in the data have to be manually harmonized, e.g., the dimensions of the machine

Can a certain product be manufactured in a production line?
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Use Case: Manufacturability Analysis

1. Data silos comprising semantic interoperability conflicts
2. Domain ontologies to capture the knowledge and resolve conflicts
3. Mappings to connect data silos with the domain ontologies
4. Describing general entities to be used in the I4.0 domain with the CIMM
5. KG enables the execution of queries to answer questions for the Manufacturability Analysis
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Use Case: Line Information System

Which production lines comprise machines from Manufacturer X?

Which production lines are currently installed in our plants?

A KG-based ecosystem capable of **semantically harmonizing and integrating manufacturing data**
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Use Case: Line Information System

Currently in use in more than 11 plants integrating data of more than

- 1,100 production lines,
- 16,000 physical machines,
- 13,000 manufacturing processes

After the first MVP, with the data semantically harmonized and integrated, more than five applications requested data to the system
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Use Case: Line Information System

Data Mesh architecture having FAIR principles right on top priority

Data products should all meet FAIR principles
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Discussion

- **Integrated 360-degree view of data**
  - Enabled experts to access semantically integrated data to answer business questions that could not be answered with data spread in silos.

- **Involvement of domain experts**
  - Making *domain experts* part of the process to understand, clean, share and enhance data was – and still is – core to the approach.
  - More than 400 domain experts trained in KG-related technologies.

- **Data reusability**
  - Increasing need of applications to reuse data from KG-based solutions to avoid unnecessary data duplication.

- **Impact on data quality**
  - For the first time it is possible to make the data quality of the integrated systems transparent. The findings are used to fix undetected failures in data.
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Where we want to go (And already started)

- **Full Data Fabric & Data Mesh**
  - Unification/full implementation of the Data Fabric & Data Mesh concept as part of the Data Strategy in the organization implementing **FAIR** principles

- **Performance and scalability**
  - To be have a successful present and future we need to enhance performance and scalability of KGs

- **Search engines**
  - Google-like search engines on top of domain specific KGs

- **AI/ML on top of KGs**
  - AI/ML algorithms may be able to predict results, e.g., maintenance, most common errors in production, recommender systems
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Questions?

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