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FDOs for BatCAT

Implementation of FDOs in a Data Space for Battery Manufacturing

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Abstract. This contribution explains how FDO are used in the BatCAT Consortium to support the data exchange between partners in an EDC-based Data Space. FDOs play a major role for sharing machine-actionable data in the BatCAT Data Space. However, there are still open questions regarding the FDO Specifications and practical challenges in using FDOs. The BatCAT project will further investigate practical solutions but the challenges should be addressed by the FDO Community as a whole as well in order to agree on standardized solutions and to guide future FDO adopters.

Keywords: FDO, Handle System, Data Stewardship, Data Space

1. Introduction

BatCAT (Battery-Cell Assembly Twin) is a research and innovation project funded by the EU's Horizon Europe programme. The project is a collaboration between 18 partner organisations from 9 European countries. BatCAT is developing a digital twin for the optimization of industrial battery cell production for two technologies: Li-ion and Li-S coin cells and Redox Flow batteries. The digital twin of the battery cells and the assembly lines will assist the design of new batteries and the operation of the battery assembly lines with a decision support system facilitating statistical methods, multi-criteria optimization, and Explainable Artificial Intelligence. BatCAT has analysed the data landscape and infrastructure related requirements [1]. These include the machine-actionable sharing of data using a trusted infrastructure, the collaborative creation of meta data schemas suitable for a variety of applications, and verifiable adherence to FAIR[FAIR] principles. For this purpose, BatCAT operates an EDC-based[3] Data Space[4] with Handle-based[5] FDOs[6] as the registry infrastructure and LinkAhead[7] as a distributed Data and Knowledge Management System (DKMS). The implementation of FDOs in the BatCAT consortium is based on conceptual results of the FDO Connect project, and conceptual results and software developed for the FDO One and FAIR Dataspaces projects.

2. FDO and Data Space Infrastructure

From a technical point of view, the main components of the BatCAT Data Space are the Data Space nodes which are EDC-Connectors deployed by participants of the Data Space. These nodes use the Eclipse Data Space Protocol to negotiate the access to datasets offered by the participants. The dataset offers are being described by DCAT catalogues published by the Data Space Nodes, accessible for Data Space participants. The LinkAhead system is

being used to gather data from various sources, e.g., from the electronic lab notebook ELabFTW or from the timeseries database InfluxDB containing sensor data from the assembly line prototypes. The data can then be shared with partners of the consortium. This can be initiated manually or automatically. LinkAhead operates the ECD-Connector and automatically creates data offers and handle the transfer. LinkAhead creates Handle PID for all datasets. The Handle Records conform to the BatCAT FDO Profile, 21.11172/batcat-profile-v1. The DCAT datasets use the same PID for identifying the data offers persistently and mirror the metadata from the Handle Records.

3. FDO Concepts

The recently submitted "Report on Data Stewardship and Good Practice"[2] offers practical guidance for the partners of the consortium and includes the agreed-upon minimal requirements for metadata records of data published by the consortium for restricted and public access and defines the BatCAT Handle Record Profile:

1. Obligatory (MUST) Attributes

- 21.T11966/FdoProfile — PID of the BatCAT Handle Record Profile (v0.1).
- 0.TYPE/URL or 10320/loc — Landing-page URL.
- 21.11172/dateCreated — ISO 8601 creation timestamp.
- 21.11172/versionId — Opaque 160bit version identifier (or longer).
- 21.11172/digitalObjectPolicy — Link/PID to the policy covering lifecycle rules (embargo, retention, access, tombstoning).

2. Optional (SHOULD, if applicable) Attributes

- 21.11172/license — Link/PID to license (in case of publicly available data).
- 21.11172/dateModified — ISO 8601 timestamp of last modification.
- 21.11172/authors — List of attributable authors of the data (not publishers or curators).
- 21.11172/citation — Recommended citation of this dataset.
- 21.11172/keywords — List of keywords.
- 21.11172/provenance — Link/PID to provenance information.
- 21.11172/versionTag — SemVer 2.0.0 compliant version tag.

Every PID Record published by the consortium is required to explicitly reference this profile using the 21.T11966/FdoProfile. The Profile Definition lists obligatory and optional Attributes via the PID of the Attribute Definition. According to the FDO Specifications, optional properties may or may not be present which weaker than the BatCAT wording. The Attribute Definitions are independently existing FDOs and follow the concepts developed in the FDO Connect project.

4. Challenges

Technically, the publishing of Handle Records and DCAT Datasets conforming to FDO standards and also the process of transferring data using the DSP is well-understood. However, further research is needed in the effective combination of Handle-based FDOs with semantic web technologies. The battery manufacturing community and related communities like material sciences or chemistry, have advanced considerably in creating and using ontologies (BatINFO, EMMO, VIMMP, MatWerk) for machine-interpretable data. It is important to establish a way to reuse the concepts from widely-used ontologies as FDO Profile Definitions and FDO Attribute Definitions in Handle-based FDO. This also holds for concepts from schema.org, PROV-O, PAV, or DC-Terms. The current BatCAT Handle Record Profile mirrors some of these concepts (e.g. 21.11172/dateCreated which is an equivalent property of <http://purl.org/pav/createdOn>).

Also, the current BatCAT Handle Record Profile is expressly declared as a minimal requirement. This bears the question how different applications can adapt this into a more expressive variant. Currently, there seems to be only one approach, that is, copy-pasting of the existing Profile Definition and creating another FDO Profile which effectively entails original one but is distinct. The FDO Specifications do not specify how the reuse of FDO Profiles Definitions may be implemented, whether by allowing to add multiple FDO Profiles Attributes to a single Record, by allowing to have a multi-valued FDO Profile Attribute in the Record, or by defining a mechanism for inheritance. Furthermore, the "Report on Data Stewardship and Good Practice" also recommends using immutable FDO Attribute Definitions and FDO Profile Definitions in order to guarantee persistent validity of FDO Records. However, there is currently no established way to define such immutable FDOs and the FDO Specifications do not mention immutability at all.

5. Summary

This contribution explains how FDO are used in the BatCAT Consortium to support the data exchange between partners in an EDC-based Data Space. FDOs play a major role for sharing machine-actionable data in the BatCAT Data Space. However, there are still open questions regarding the FDO Specifications and practical challenges in using FDOs. The BatCAT project will further investigate practical solutions but the challenges should be addressed by the FDO Community as a whole as well in order to agree on standardized solutions and to guide future FDO adopters.

Data availability statement

No data collected.

Underlying and related material

The Github Group contains software, ontologies and the Data Stewardship Repository: <https://github.com/HE-BatCAT>.

Author contributions

TF: Conceptualization, writing – original draft. MB: Conceptualization, supervision, writing – review and editing. MTH: Conceptualization, supervision, project administration, writing – review and editing.

Competing interests

The authors declare that they have no competing interests.

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