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Challenges and Opportunities of Semantic Information Management and Cross Domain Linking in the Context of Manufacturing

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Abstract. In the era of digital information provisioning, companies face the challenge of efficiently managing and linking technical product information across various systems. This paper describes the introduction of Semantic Information Management (SIM) in a manufacturing company, focusing on the efficient management and linking of technical product information across different systems. The structured development process, based on a combination of two sub-ontologies (Component Content Management System and Spare Parts Catalogue) and Semantic Correlation Rules (SCR), ensures that content can be efficiently organized and delivered. By implementing SCR, the project establishes a flexible framework for the creation of knowledge graphs based on metadata and maintaining relationships between information. Companies aim to provide technical information in a targeted, comprehensible, and user-oriented manner. However, fragmented system landscapes hinder this process. SIM addresses these challenges by enabling standardized data modeling, dynamic content linking, and cross-domain interoperability. The standardized implementation not only fosters information integration between domains but also lays the foundation for future innovations in digital process automation and knowledge management.

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INTRODUCTION

In an increasingly data-driven world, companies are facing the challenge of preparing technical product information in a targeted, comprehensible and user- oriented manner. Especially in the context of digital information services and automated processes, the linking, management and provision of technical information becomes increasingly more important in the field of technical communication (TC) [1]. Semantic information management technologies, methods and strategies play a central role in meeting these requirements. However, the implementation of such technologies in companies can be complex, especially if there is little experience with semantic modelling. Companies often work in a diverse and fragmented system landscape in which information is created, processed and managed in different source systems. This fragmentation hinders the efficient provision and reuse of information for user-centered purposes. Semantic technologies enable an efficient and user-oriented provisioning of information despite the use of different source systems. This is achieved through standardized data modelling and the dynamic linking of content using cross-domain ontologies and Semantic Correlation Rules (SCR). The modeling basis for the SCR consists of use cases that represent specific usage scenarios assumed by the company. SCRs offer a standardized and data-independent information architecture that enables the flexible and context- dependent provision of information. A core concept of Semantic Information Models (SIM) is the so- called MicroDocs - they offer a structured collection of relevant information tailored to specific use cases. Together, ontologies, SCR and MicroDocs form the base for user-centered technical information management [2].

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OBJECTIVES AND INITIAL SITUATION

The main goal of the project was to improve the provision of information in companies in the long term. To achieve this, ontologies were developed as the base for metadata modeling and further refined with the help of SCR. This approach should enable a flexible, domain-specific information management system and facilitate the application-driven provision of content.

Ontologies, such as the SIM, form the base for modeling metadata and can be extended with SCR. The SIM approach makes it possible to model domain-specific information and use it for various purposes as illustrated in [7]. The first step of the research work was analyzing two data sources from a manufacturing company active in the fields of wood-based materials, forming and recycling. Specifically, the spare parts catalog (Product Engineering Domain) and the CCMS metadata (Content Engineering Domain) were evaluated to assess the quality and applicability of the company's data [3]. Users use SPC to search for spare parts and technical details and CDP to access technical documentation. Both systems are often used independently of each other. However, in terms of a semantic information model, it makes sense to link the content intelligently.

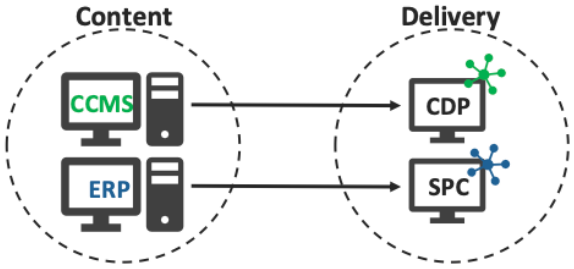

Figure 1 System landscape of the company: Content and data creation on the left (CCMS, ERP) and Information Delivery on the right (CDP, SPC).

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METHODOLOGY

This paper describes the creation and implementation process of SCR after ontology creation. It outlines the usage of use cases, the implementation of the SCR and the use of the API for provision in the Content Delivery Portal (CDP). The ontology creation is explained in [7].

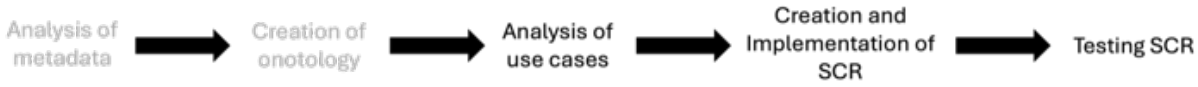

Figure 2 Project process

Use Cases

The use cases were developed by the company to represent typical application scenarios and address user needs (figure 2). Three types of use cases can be distinguished in this project:

- From SPC to CDP to obtain further information on a spare part.
- From CDP to SPC to gain an overview of products and associated spare parts.
- Within CDP to retrieve additional information on an already known spare part. Semantic Correlation Rules were created based on these use cases.

The use cases were created according to the aim of SIM to enable the linking of relevant information from both systems and thus improve the user experience and provide information consistently and contextually.

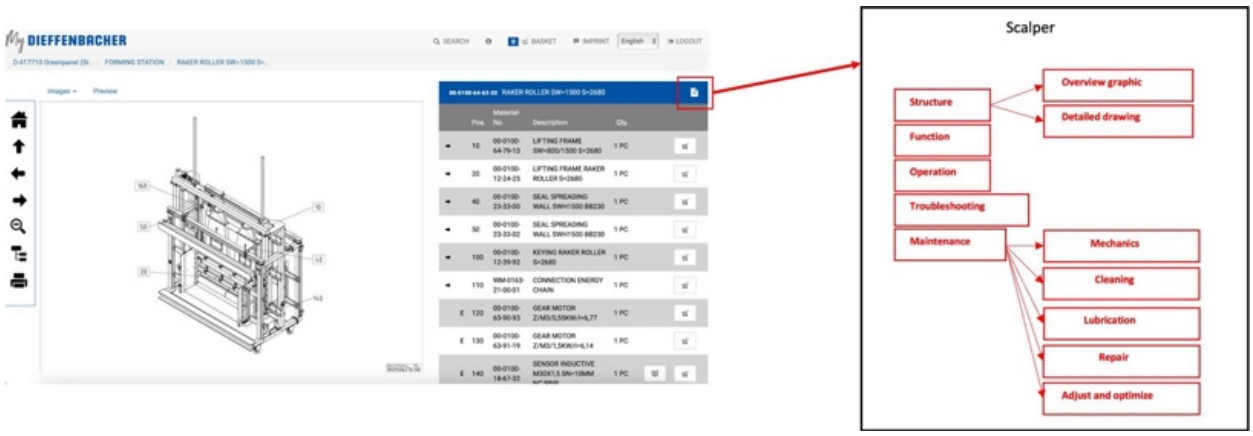

Figure 3 Use Case from SPC to CDP delivered by the company

In this use case (figure 3) the user looks at the spare part scalper in the spare parts catalog and wants to call up further information.
The first step in systemically mapping the use cases was to collect the derived information in an Excel file to develop SCR. For example, start and end points were identified.

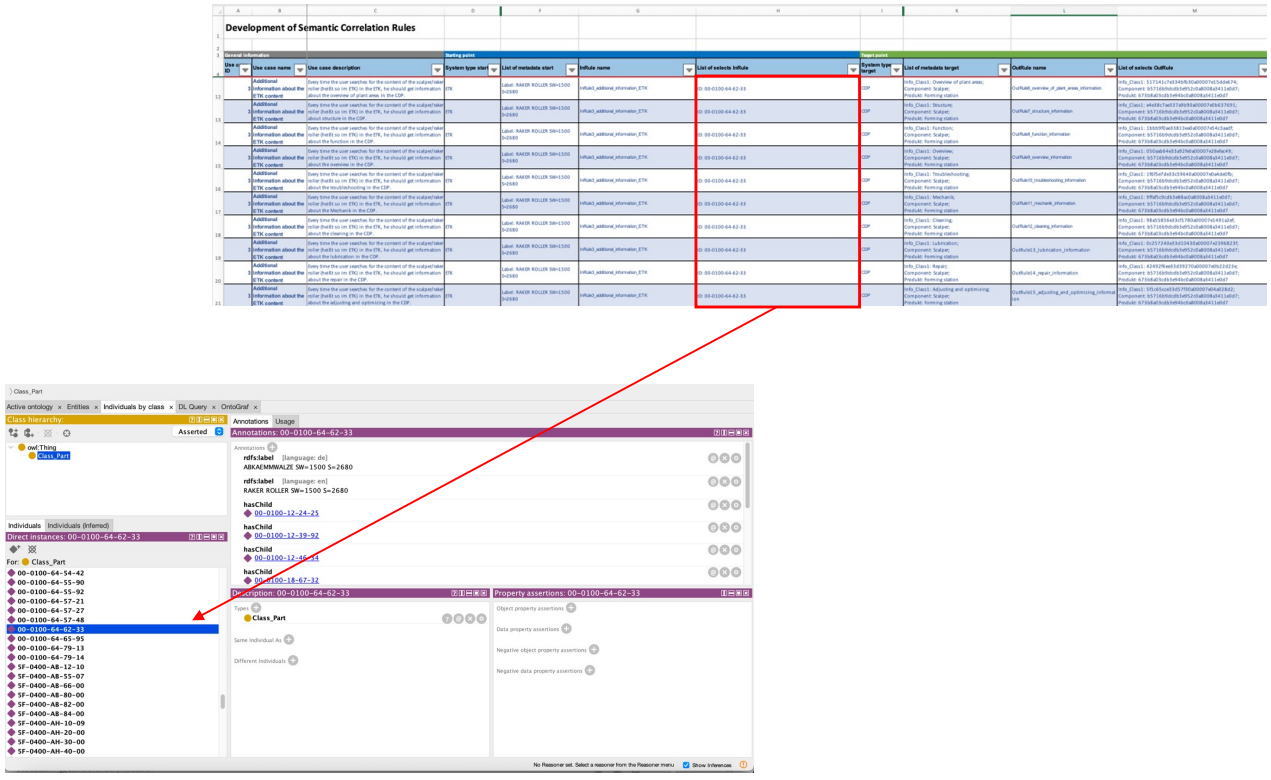

Figure 4 Example: How the data from the ontology served as a foundation for mapping the use cases using appropriate SCR

The identified start and end points were supplemented with the corresponding metadata, which can be retrieved from the ontology. This figure (4) provides an example of how they serve as a foundation for mapping the use cases using the appropriate SCR.

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Semantic Correlation Rules

Based on specific use cases, SCR define logical relationships between metadata, creating flexible, context-sensitive, and reusable information structures. They are based on the metadata environment or the use cases derived from it, which were provided by the company [1]. SCR can be used to create links between different metadata. They also make it possible to define and show the relationships and dependencies between the different topics within the systems. In this way, the use cases can be mapped across domains [1].

The following visualization (figure 5) shows an example of SCR in an GraphDB triple store [https://graphdb.ontotext.com]. GraphDB supports the Resource Description Framework (RDF) and enables queries and analyses using the SPARQL query language. It also serves as a tool for indexing and linking knowledge from different data sources [5].

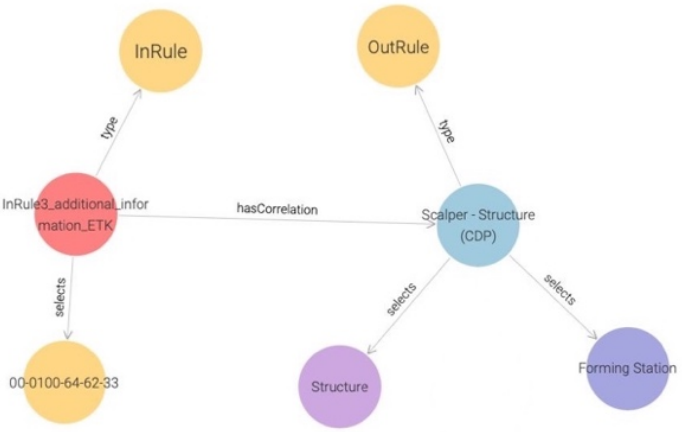

Figure 5 Semantic Correlation Rules in GraphDB

The SCR in figure 5 illustrate the use case in figure 3. The InRule shows the spare part with the respective metadata from the spare parts catalog, while the corresponding OutRule shows the corresponding topic for the structure of the scalper in the content delivery portal as well as the associated metadata.

A script using SPARQL queries (figure 6) was developed to create SCR (figure 5) and insert the InRules and corresponding OutRules in the knowledge Graph stored in the GraphDB environment. This allows for an efficient definition and visualization of relationships and dependencies between various metadata.

The InRule determines the relevant metadata for the starting point of a use case and simultaneously identifies the appropriate OutRule that creates the corresponding link. The OutRule in turn defines the relevant metadata for the target of the use case and ensures structured further processing of the information [2, 5].

```
37
38 scr:InRule3_additional_information_ETK rdf:type scr:InRule.
39 scr:InRule3_additional_information_ETK scr:selects DFB:00-0100-64-62-33.
40 scr:InRule3_additional_information_ETK scr:hasCorrelation scr:OutRule7_structure_information.
41   #InRule3
42
43 scr:OutRule7_structure_information rdf:type scr:OutRule.
44   scr:OutRule7_structure_information scr:selects DFB:e4e38c7ae337a9b90a00007e0b637691.
45   scr:OutRule7_structure_information scr:selects DFB:b5716b9dcdb3e952c0a8008a3411e0d7.
46 scr:OutRule7_structure_information scr:selects DFB:673b8a03cdb3e94bc0a8008a3411e0d7.
47   scr:OutRule7_structure_information scr:equals DFB:b5716b9dcdb3e952c0a8008a3411e0d7.
48      scr:OutRule7_structure_information rdfs:label "Scalper - Structure (CDP)".
49 #OutRule7
50
51
```

Run
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Figure 6 Excerpt of SPARQL insert queries script to develop and implement SCR

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As can be seen in figure 5, it is first determined whether it is an InRule or an OutRule (rdf:type), then the corresponding metadata is appended with the “selects” command. In the case of InRules, the corresponding OutRules (hasCorrelation) are also linked. The figure shows how the use cases are displayed on the system side.

API (Application Programming Interface)

Once the SCR from figure 5 had been developed and implemented by SPARQL queries, they were implemented in a server application providing an SCR-API [1] and finally tested using the Postman software package. Postman is an interface platform on which APIs can be designed, created, further developed and tested. The SCR-API was needed to be able to retrieve data from API endpoints in a standardized way without having to access the GraphDB directly. This is because the API acts as an interface between the GraphDB and applications such as CDPs [6]. API also provides deep links in addition to the metadata.

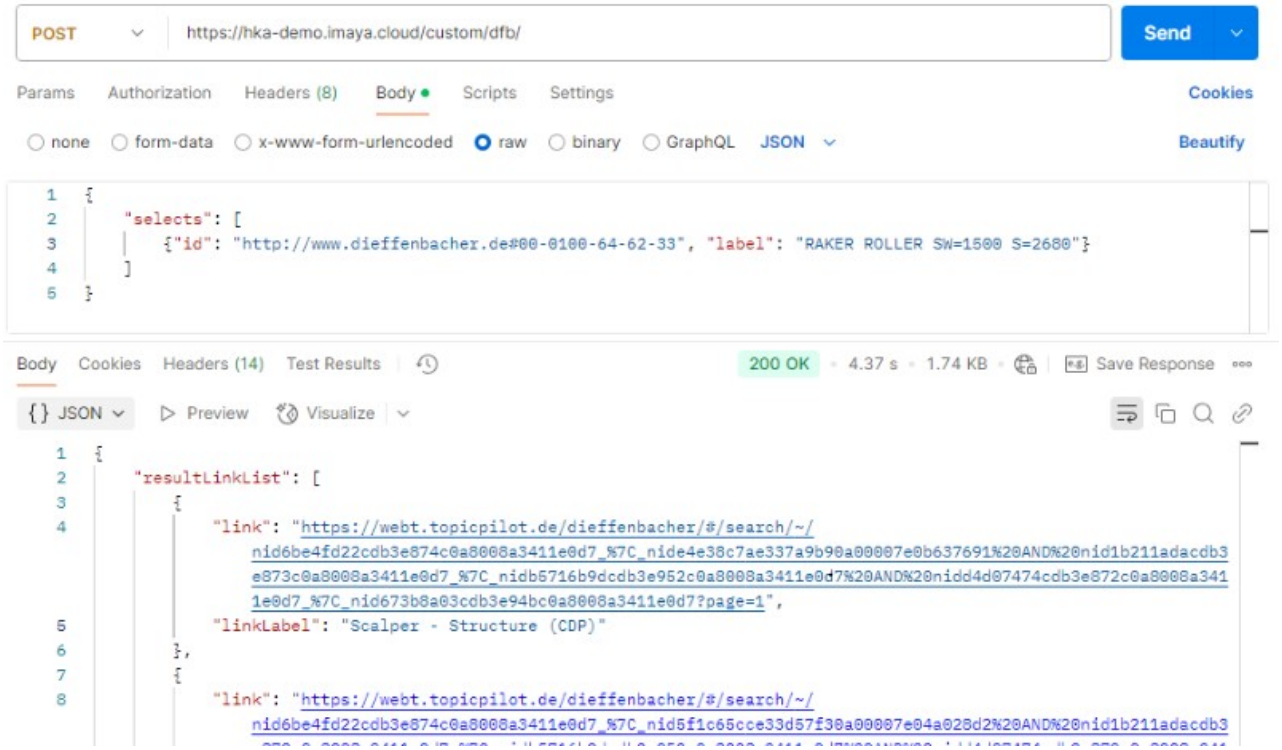

Figure 7 Excerpt from Postman during the testing of SCR

The result links, which can be seen in figure 6, are displayed in the systems as deep links.

FINDINGS

During the project, the quality and harmonization of the data within the entire system landscape proved to be decisive factors for the success of ontologies and Semantic Correlation Rules (SCR). Inaccurate or inconsistent data impairs the functionality of the systems, which is why targeted measures were implemented to ensure data quality.

Throughout the project, it became clear that the consistency of metadata and effective terminology management are of central importance. Only if metadata is logically structured and consistent, information can be precisely assigned and made available in a targeted manner.

Various challenges arose over the project's timeline. One key finding was that there were discrepancies between the metadata of the SPC and the original CCMS. These differences were gradually aligned over the course of the project, with the identified weaknesses serving as the basis for optimization. This created the base for improved standardization and a more precise formulation of the SCR.

Another problem was the inconsistent naming of certain metadata in different places. This made it difficult to clearly assign terms and led to misunderstandings in communication. This made it clear how important uniform terminology is, as it makes a decisive contribution to improving clarity and collaboration in the project.

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RESULTS AND OUTLOOK

As part of the project, both ensuring data quality and integrating heterogeneous system landscapes were addressed. The approaches presented form the base for targeted, cross-media information processing that optimizes internal processes and improves the user experience at the same time. In addition, the structured development process, based on a combination of two ontologies (CCMS and SPC) and SCR, can ensure that the industrial company can organize and provide content efficiently.
The result of the use case from SPC to CDP used as an example in this paper (see figure 2-5) would result as follows:

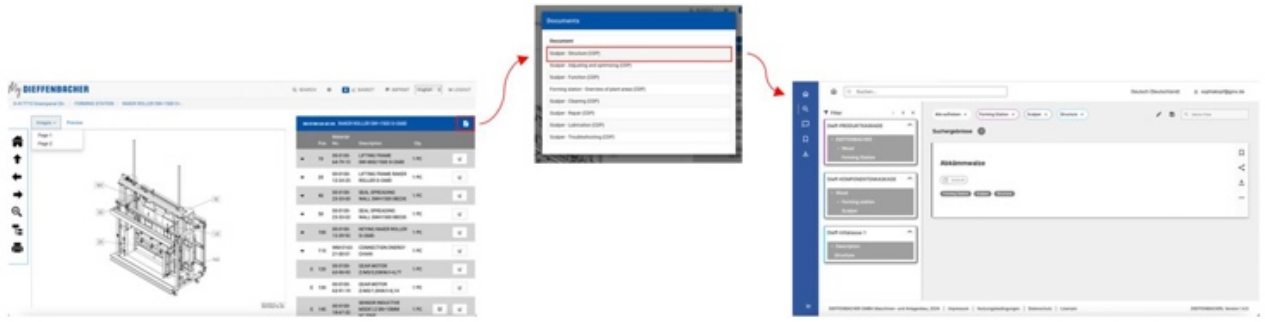

Figure 8 Result of the use case used as an example (SPC to CDP)

To provide another example of the three different types of use cases, the following figure (8) illustrates a link from CDP to SPC.

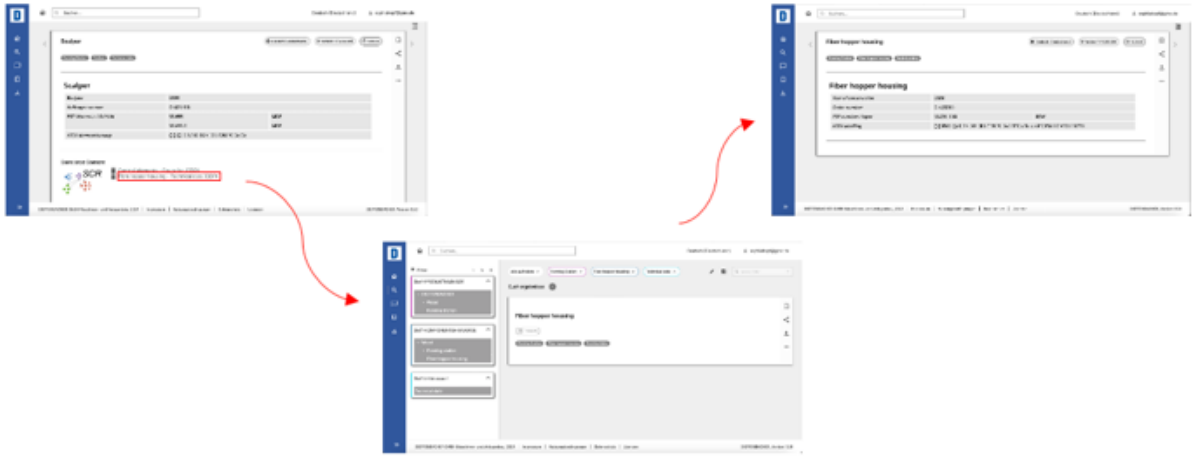

Figure 9 Result of the use case from CDP to SPC

To exploit the full potential of the SCR, continuous expansion of use cases are required. A larger number of SCRs enables a more precise provision of content in the respective usage context. The targeted expansion of the SCRs can further optimize the linking of these systems and ensure a dynamic, user-oriented delivery of information. In a scenario where delivery systems provide access to user behavior, web analytics and corresponding pattern analysis can also give ways to extract SCR automatically. For quality assurance the rules could still be curated in a SIM/SCR environment.

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