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Ontology-Driven Natural Language Query System for Fusion Maintenance Planning

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The increasing complexity of fusion facilities demands robust data governance strategies capable of integrating heterogeneous knowledge sources while ensuring semantic consistency, traceability, and regulatory compliance. This talk presents an ontology-based data governance model as the foundational architecture for a Natural Language Query (NLQ) system designed to support maintenance planning in fusion facilities. We argue that the successful implementation of such an ontology-driven approach is contingent upon a high level of maturity in "classical" corporate data governance. Without a solid foundation of data quality, stewardship, and standardized master data management, the higher-level semantic framework lacks the structural pillars necessary for reliable knowledge representation.

The proposed governance framework establishes a formal ontological structure that harmonizes maintenance taxonomies, component hierarchies, failure mode classifications, and procedural constraints within a unified semantic layer. By grounding advanced data governance in ontological principles, the model enforces controlled vocabularies, domain axioms, and inference rules that preserve data quality and interoperability across distributed maintenance information systems. Built upon this governance backbone, the NLQ system translates unstructured maintenance queries posed by engineers and planners into structured SPARQL expressions, leveraging the ontology as both a semantic mediator and a validation mechanism.

The system architecture integrates large language models with ontology-driven entity recognition and relation extraction modules, enabling context-aware disambiguation of maintenance-specific terminology such as remote handling sequences, radiation exposure thresholds, and component lifecycle states. Evaluation on a corpus of representative maintenance planning queries for IFMIF-DONES subsystems demonstrates that this governance-anchored approach yields significant improvements in query precision and recall compared to schema-agnostic baselines, while simultaneously enforcing compliance with safety and quality assurance standards. The results confirm that the transition from mature corporate governance to ontology-based semantic layers constitutes a critical enabler for intelligent, linguistically accessible decision-support tools in next-generation fusion engineering environments.

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