Clinical Data Modeling with SULO

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Abstract
Designing high-quality ontologies that are Findable, Accessible, Interoperable, and Reusable (FAIR) remains a key challenge in practice. This tutorial introduces a fully integrated workflow for ontology engineering using SULO, a lightweight upper-level ontology designed to guide conceptual representation and implementation in OWL; OntoStart, a GitHub-based framework for creating FAIR ontology projects with automated quality checks; and two complementary tools for constructing and reasoning with ontologies - Protégé and owlready2 in Python. Through a hands-on, end-to-end example, participants will conceptualize and formalize the well-known concepts from clinical domain using SULO design patterns, implement it in OWL, evaluate it with automated pipelines, and query or reason over it programmatically. The tutorial is aimed at researchers, students, and practitioners building domain ontologies or data schemas. Participants will leave with a repeatable workflow, template repositories, and practical skills to bootstrap their own FAIR ontology projects.

Keywords
Upper Level Ontology, Semantic Interoperability, Knowledge Graphs, Data validation

1. Objectives

This tutorial addresses a persistent gap in applied ontology: the absence of accessible, end-to-end workflows for producing FAIR, modular, reusable ontologies with high conceptual and engineering quality.

The tutorial objectives are to:

- Introduce a **coherent, end-to-end workflow** for engineering FAIR and principled OWL ontologies, from conceptualization to publication.
- Demonstrate the value of the Simplified Upper Level Ontology (SULO) as an upper-level ontology **to guide high-quality ontology representation** across domains.
- Showcase OntoStart as a practical framework for creating FAIR ontology projects with **automated versioning, documentation, and quality assessment**.
- **Contrast conceptual modeling and formal implementation**, using SULO patterns to motivate OWL axioms and ontology design decisions.
- **Present complementary tooling ecosystems**, including Protégé and owlready2, for interactive and programmatic ontology development and reasoning.
- **Provide a realistic, motivating domain example** (SULO Pizza Tutorial) that illustrates key modeling choices, patterns, and reasoning outcomes.
- Empower participants to adopt **reproducible, maintainable, and FAIR engineering practice** for their own ontology projects.

2. Scope and level of detail

This tutorial explains how to use the SULO ontology to represent key healthcare concepts such as conditions, procedures, and measurements. It illustrates these concepts through an administrative case

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describing a patient's encounter at a healthcare facility, including admission, discharge, observations, diagnoses, and treatments. The example case covers a care episode where the patient is admitted, has their blood pressure measured, is diagnosed with hypertension, receives medication, and is given a prescription for continued treatment after discharge.

The tutorial aims to balance theory with hands-on ontology engineering over a well known domain. The tutorial is pitched at a basic to intermediate level; no prior knowledge of upper level ontologies or OWL is required.

3. Target audience

This tutorial is highly relevant for SWAT4HCLS attendees interested in ontology engineering, knowledge graph construction, semantic interoperability, and FAIR data infrastructures, and Semantic Web tooling.

This tutorial targets:

- Researchers **new to ontology engineering** that are seeking a principled yet accessible start.
- Practitioners **seeking a simpler alternative** to existing upper level ontologies
- Students or PhD researchers aiming to build **reproducible ontology workflows**
- Developers wanting to use **python-based ontology engineering pipelines**
- Government/industry stakeholders evaluating **practical semantic tooling**.

Attraction strategy: We will create a web site hosted on GitHub and provide all tutorial materials. We will promote the tutorial through various social media (LinkedIn, BlueSky), mailing lists (e.g. SemWeb), and project channels.

4. Learning goals

The learning goals of the tutorial are twofold:

1. Develop competency in the use of SULO to conceptualize and formalise a domain

- Explain the role of an upper-level ontology and apply SULO's categories and design patterns to conceptualize a domain.
- Distinguish parts, features, roles, capabilities, processes, and quantities within a domain using SULO semantics.
- Formalize domain concepts in OWL, translating SULO-based conceptual models into logical axioms.
- Implement SULO patterns in OWL for the clinical domain and validate them using tooling.

2. Publish and maintain ontology projects following FAIR practices

- Initialize a new FAIR ontology project using OntoStart, including metadata files, documentation structure, and CI-based quality checks.
- Use Protégé Web to build, visualize, and test ontology class structures.
- Use owlready2 in Python to construct, manipulate, and reason over ontologies programmatically.
- interpret FOOPS! FAIRness reports and identify steps to improve ontology FAIRness.

5. Schedule

A half-day tutorial is structured into two parts: (1) Conceptualization and Formalisation using SULO and (2) Implementation using OntoStart, Protege or OwlReady2.

Table 1
Proposed Schedule

Time	Session
00:15	1. Introduction and Motivation
00:45	2. SULO Foundations
00:30	3. Conceptualizing the Clinical Domain
00:15	5. OntoStart
00:45	6. Formalization in OWL
00:30	7. Automated reasoning, validation, FAIR assessment, publication
00:15	8. Q&A and wrap up
3:15	

6. Other venues presented

A workshop on using SULO for healthcare interoperability will be presented at the i HD Annual Conference in Ghent, Belgium on December 2, 2025. This tutorial will be distinct in the domain of application (pizza), and in presenting a FAIR ontology engineering workflow using OntoStart.

7. Biography of the presenter(s)

Michel Dumontier is the Distinguished Professor of Data Science at Maastricht University, founder of the Institute of Data Science, and co-founder of the Department of Advanced Computing Sciences. He is a leading researcher in biomedical ontologies and knowledge graphs, FAIR data, and Semantic Web technologies. He co-founded the FAIR principles, leads major EU and US research initiatives, and has extensive experience teaching ontology engineering, knowledge graphs, and Semantic Web technologies at undergraudate and graduate level. He is a co-creator of SULO and created the ontostart FAIR ontology template project.

Remzi Celebi is an Assistant Professor in the Department of Advanced Computing Sciences at Maastricht University and a member of the Institute of Data Science. His research focuses on semantic data integration, biomedical ontologies, knowledge graphs, and machine learning methods for health applications. He has contributed to several large-scale national and European research initiatives in trustworthy and FAIR health AI, including projects on interoperable clinical data infrastructures, semantic enrichment of health datasets, and AI-supported clinical decision-making. Remzi is an experienced instructor in data science and semantic technologies, teaching courses on semantic web, knowledge graphs, machine learning, and FAIR data stewardship. He regularly supervises MSc and PhD students in areas spanning ontology engineering, heterogeneous data integration, and representation learning for biomedical data.

Declaration on Generative AI

During the preparation of this work, the author(s) used GPT-5.1 in the drafting content for this submission. The author(s) reviewed and edited the content as needed and take full responsibility for the publication's content.

References

A. Online Resources

- OntoStart GitHub

- SULO GitHub
- Protege
- FOOPS!