KNOWING WHERE VIA KNOWLEDGE GRAPH-BASED GEO-ENRICHMENT

ONTOLOGIES AND THEIR DESIGN FOR KNOWWHEREGRAPH

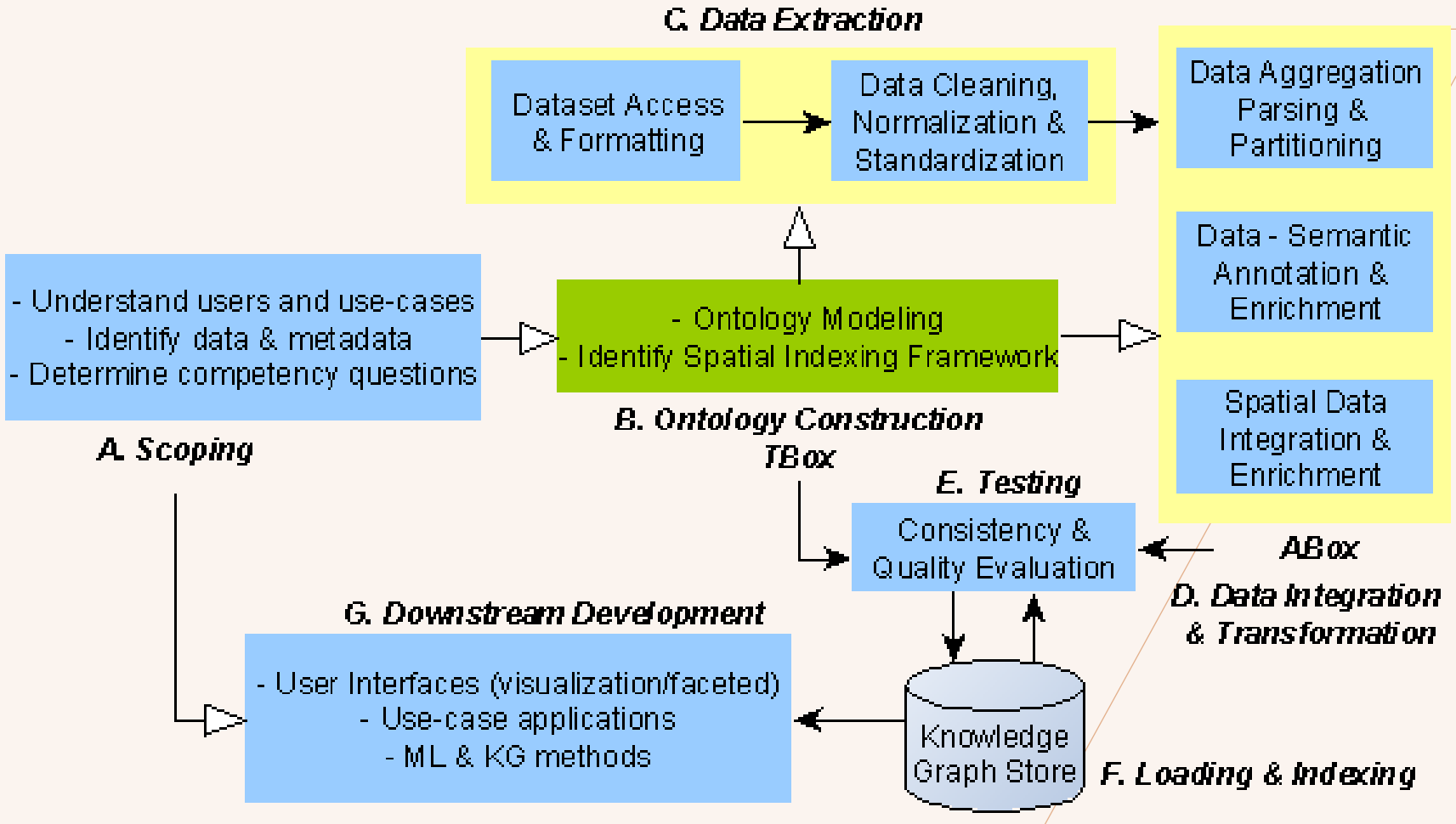
The International Semantic Web Conference 2023

Athens, Greece

Cogan Shimizu

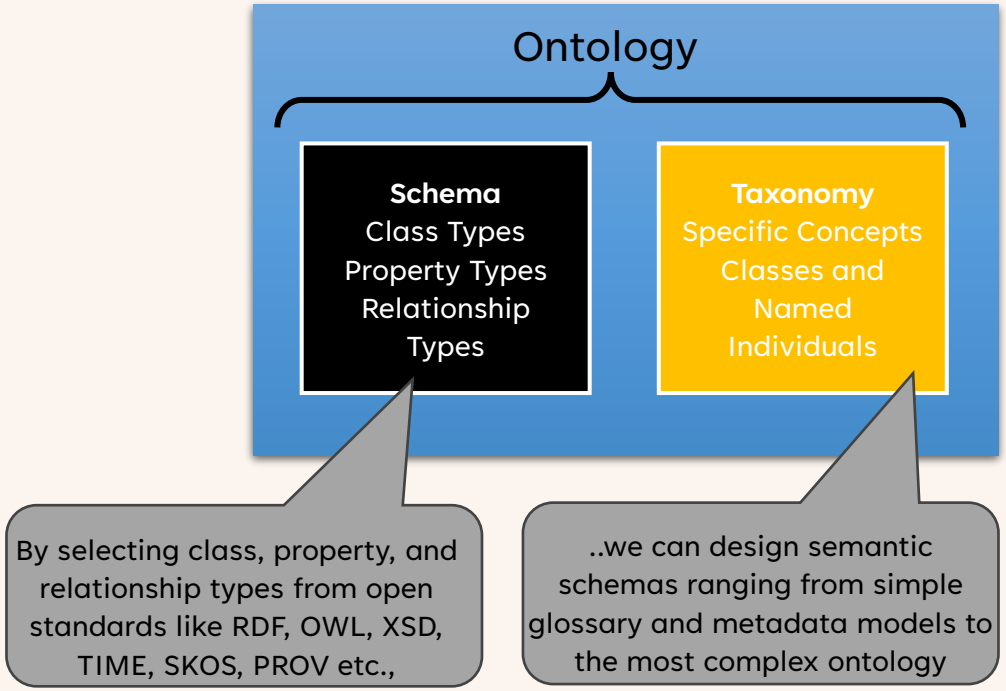
Assistant Professor, Wright State University

GENERAL STEPS IN CONSTRUCTING KNOWWHEREGRAPH



ONTOLOGIES AND KGS

Ontologies are foundational structures for knowledge graphs



A knowledge graph is when an ontology is applied to a set of interlinked real-world entities described in a formal structure...

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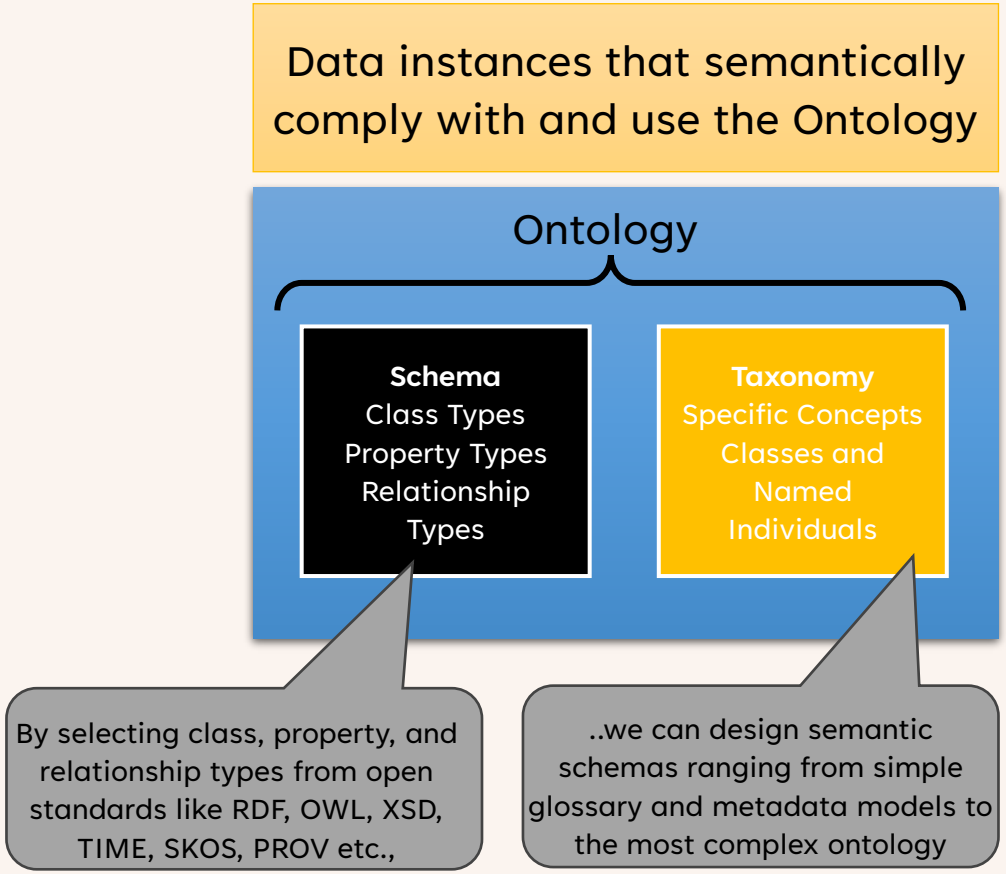

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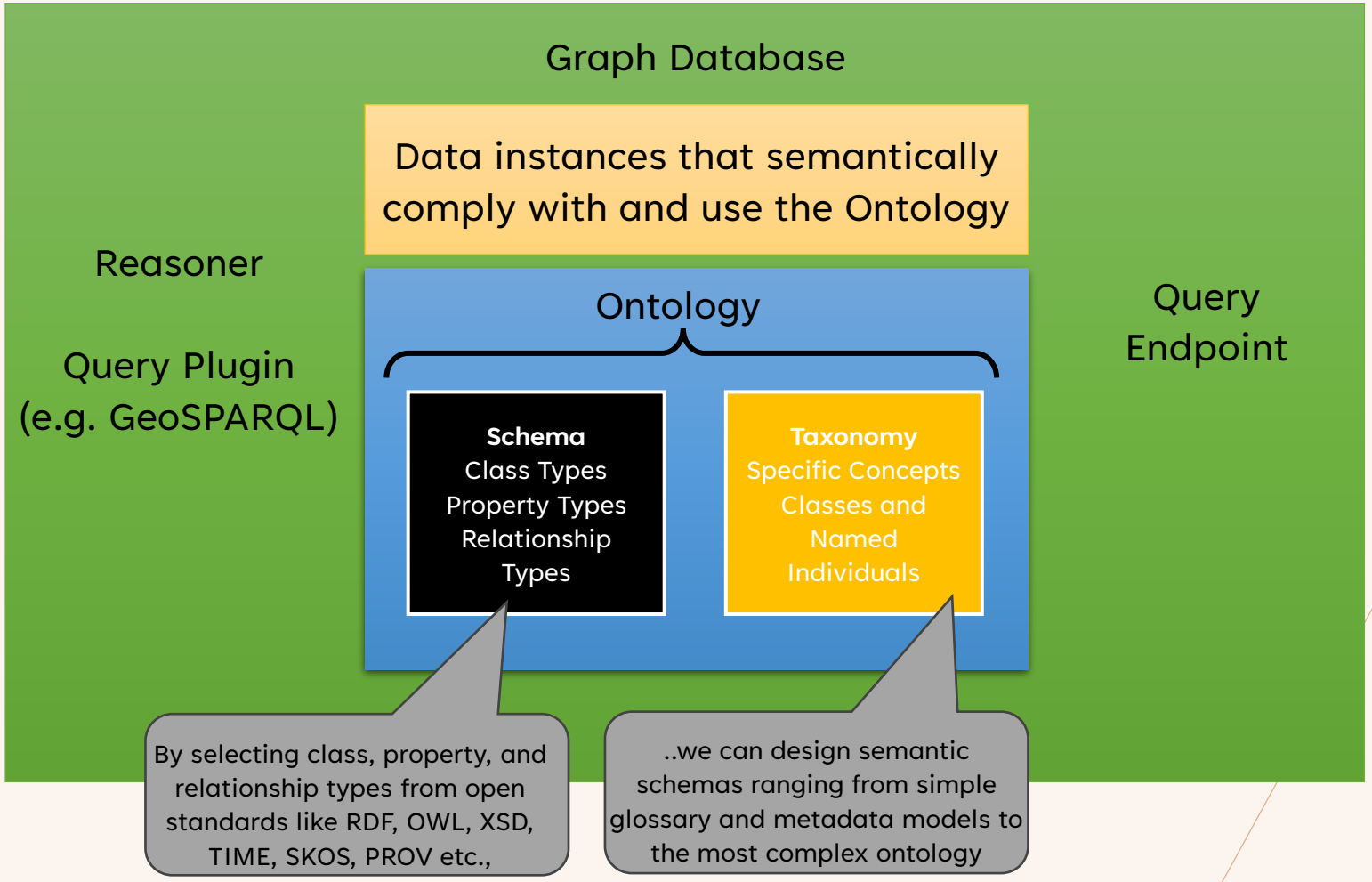

A knowledge graph is when an ontology is applied to a set of interlinked real-world entities described in a formal structure...

and applies a reasoner to reason and infer new knowledge.

GEOSPATIAL DATA IN KNOWWHEREGRAPH

- Spatial data is unique compared to other types of data in several ways:
  - relies heavily on spatial relationships that play a central role in spatial analysis and reasoning
  - can exhibit scale-dependent behaviors
  - relies on coordinate systems
  - includes complex data types, such as raster data (gridded data) and vector data (geometric data)
  - have a temporal dimension

SPATIAL DATA MODELING DECISIONS FOR KNOWWHEREGRAPH

- Adopting standardized models (specifically GeoSPARQL)
  - provides an expressive **data model** for geospatial features and geometries
  - allows geospatial data to be seamlessly **integrated** with other RDF data in a Semantic Web context
  - extends the capabilities of SPARQL to include geospatial **queries**
- Reusable
  - domain independent
  - include mappings or alignments that facilitate connections with other ontologies or data sources
- Extendable
  - adaptable to changing requirements and different types of spatial data
  - modular
- Improves data analysis (query performance + reduced computational overhead + scalability)
  - provides the ability to geo-reference non-geospatial knowledge
  - provides spatial aggregations
- Enable qualitative spatio-temporal reasoning (QSTR)

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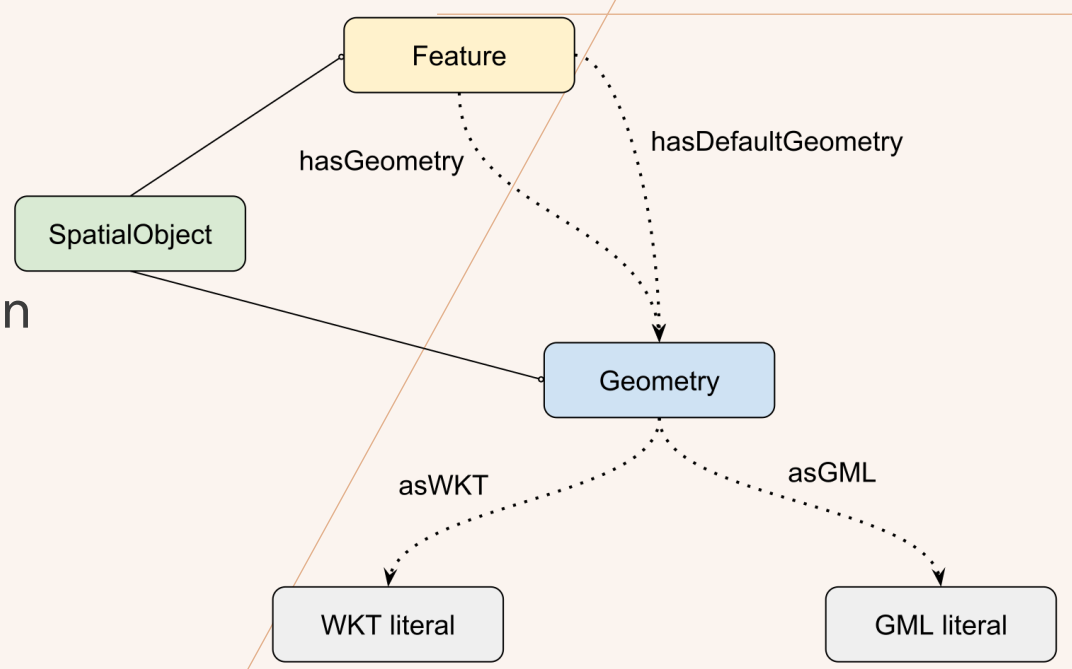
In progress

ADOPTING THE STANDARD DATA MODEL - GEOSPARQL

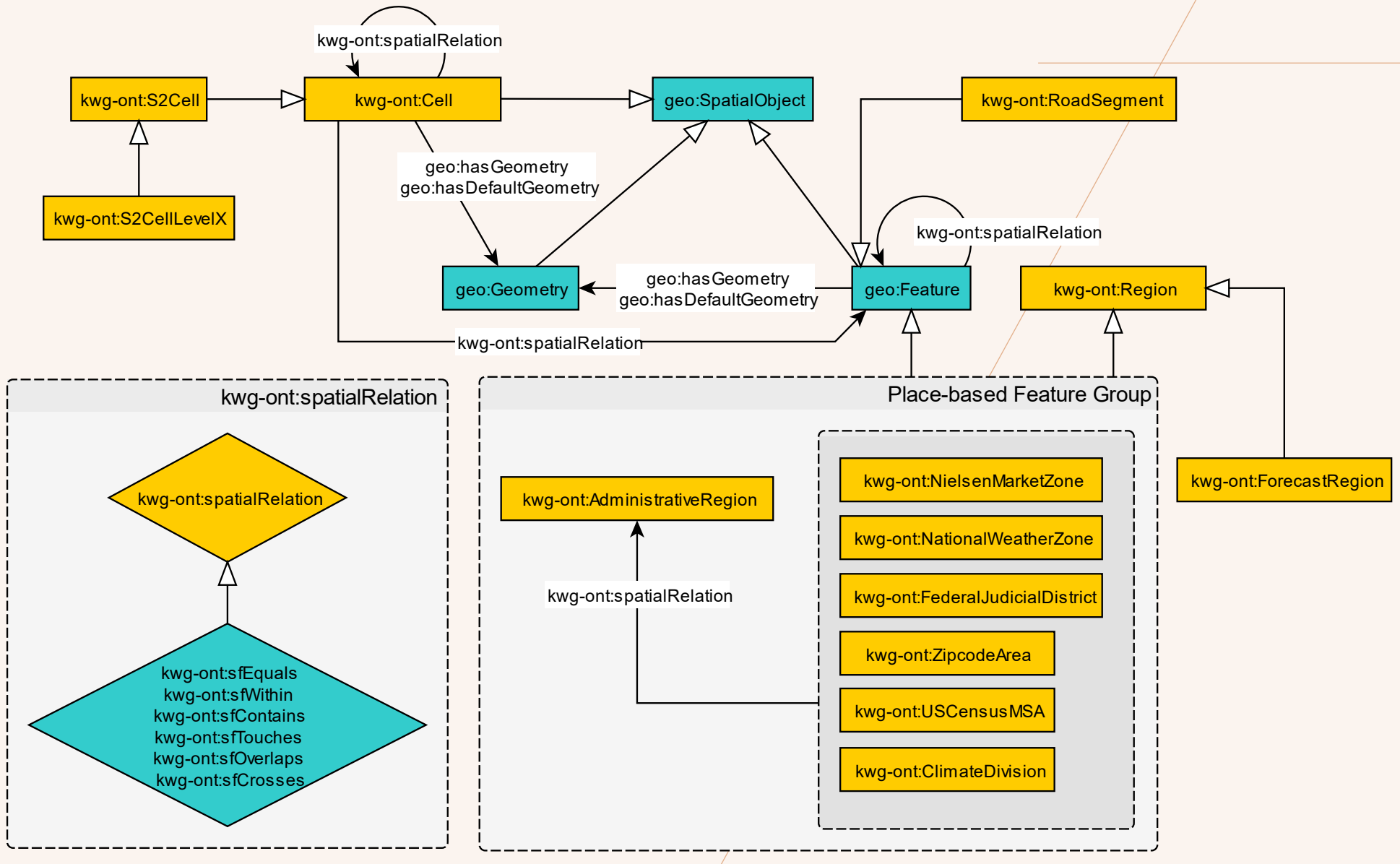
- ISO and OGC standard[1] for representing and querying vector-based 2D data
- Geometric feature classes: points, lines, polygons
- Topological and mereological relations - based on RCC-8 and Egenhofer 9-I model
- Datatypes for geometry literals
  - ogc:WKTLiteral, ogc:GMLLiteral
- Query functions
  - Topological relations, distance, buffer, intersection
- Entailment components



ISO International Organization for Standardization

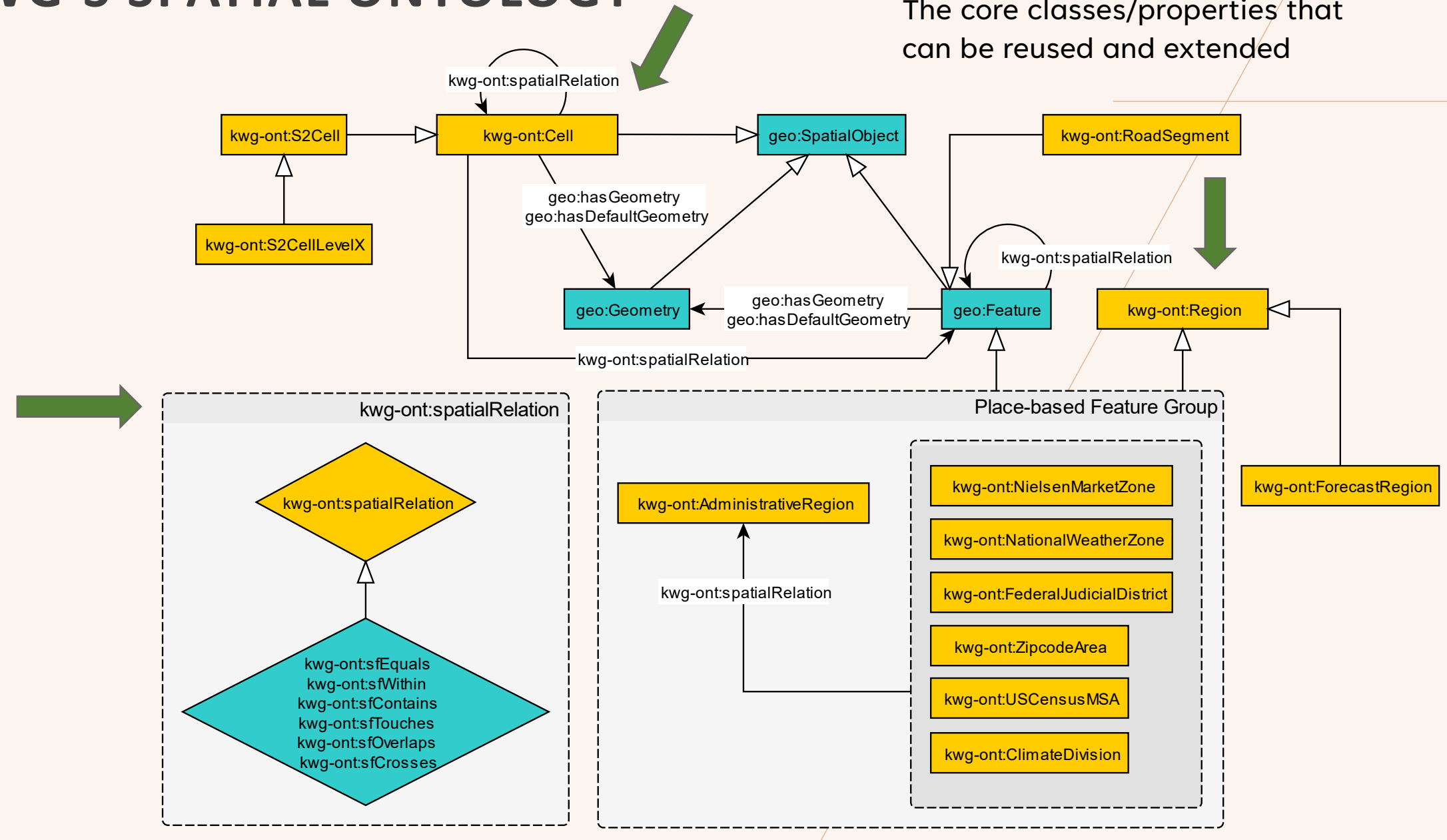
Open Geospatial Consortium

KWG'S SPATIAL ONTOLOGY



KWG'S SPATIAL ONTOLOGY

The core classes/properties that can be reused and extended



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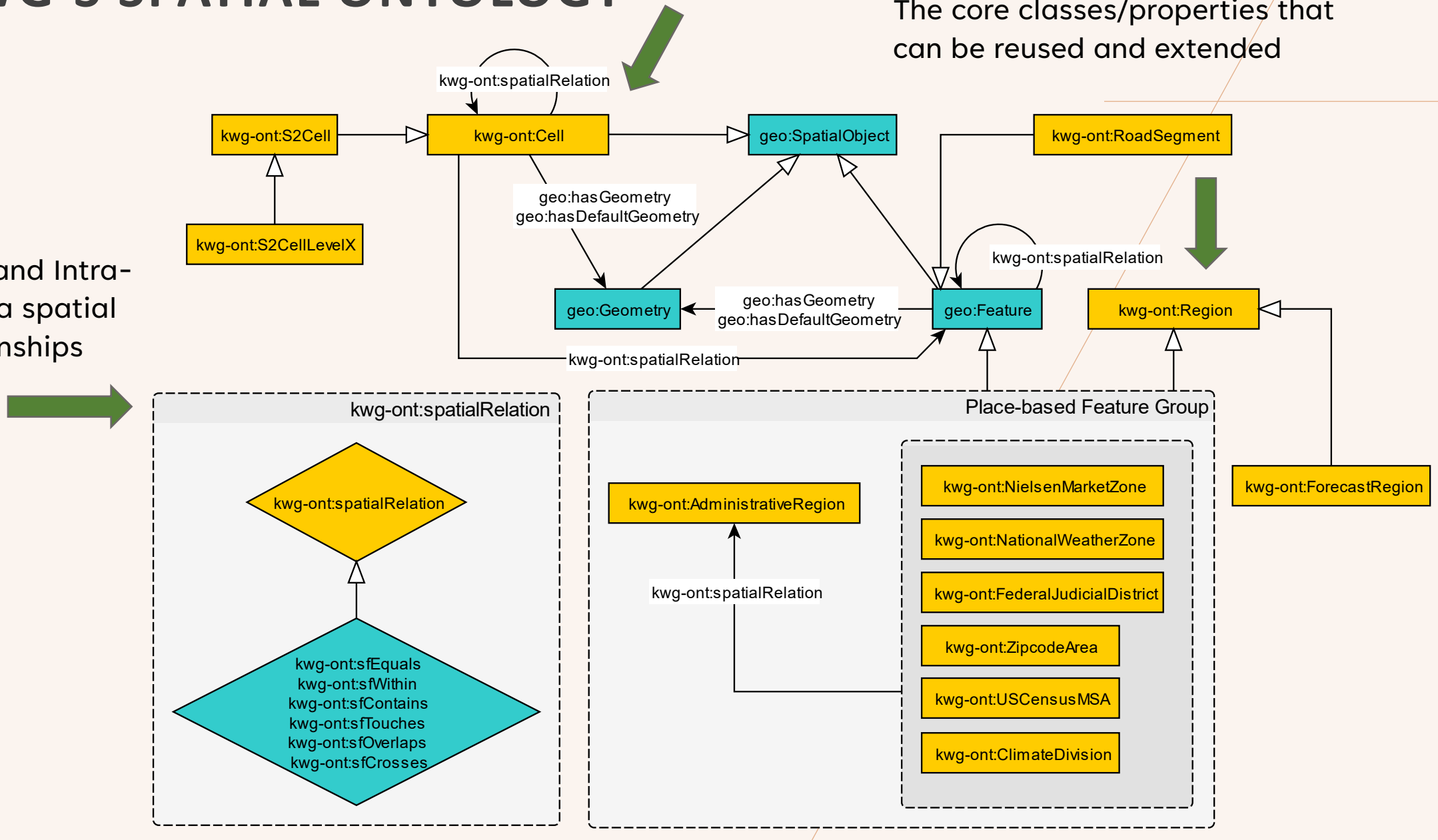
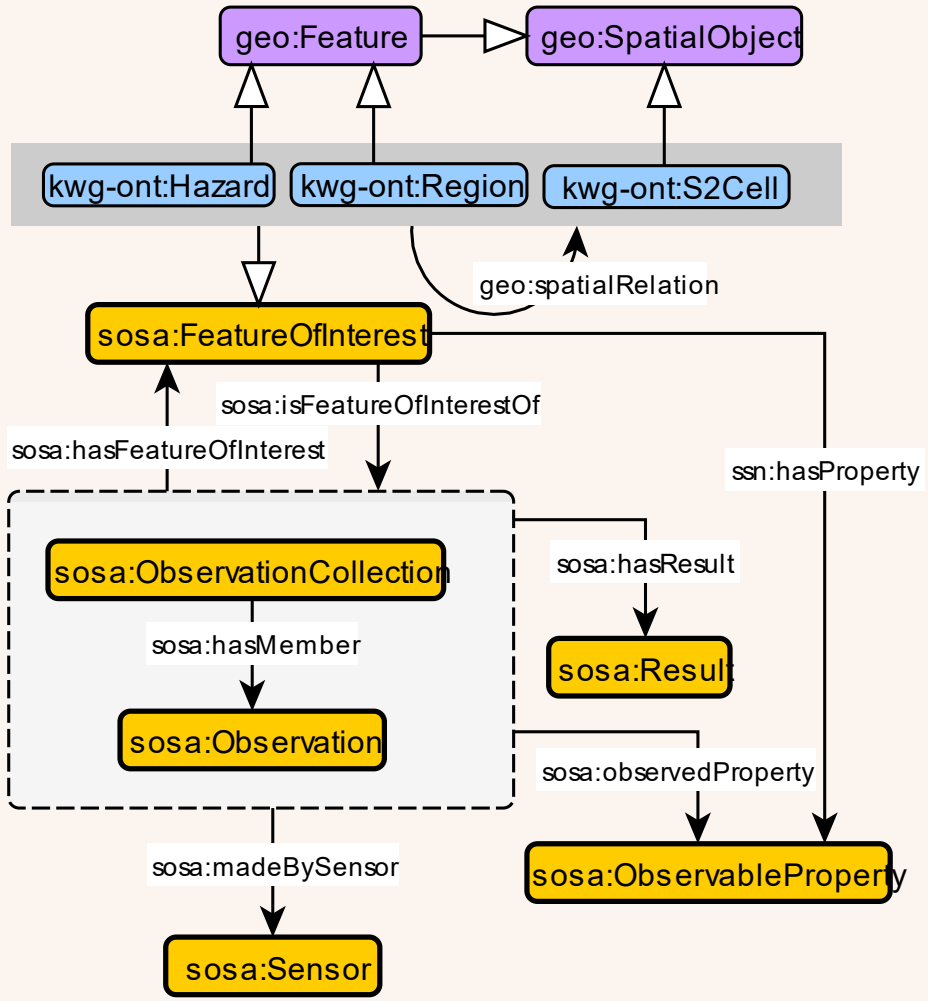
Inter- and Intra-schema spatial relationships



GEOREFERENCING AND SPATIAL INTEGRATION



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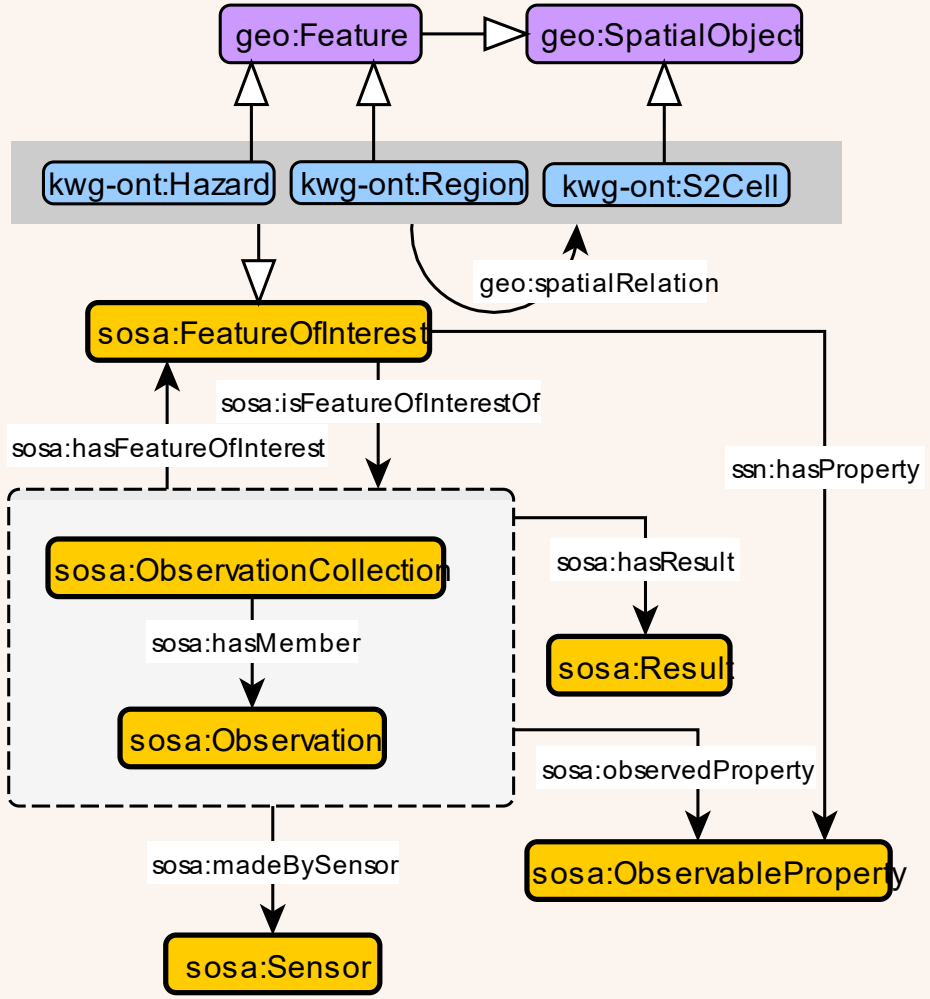
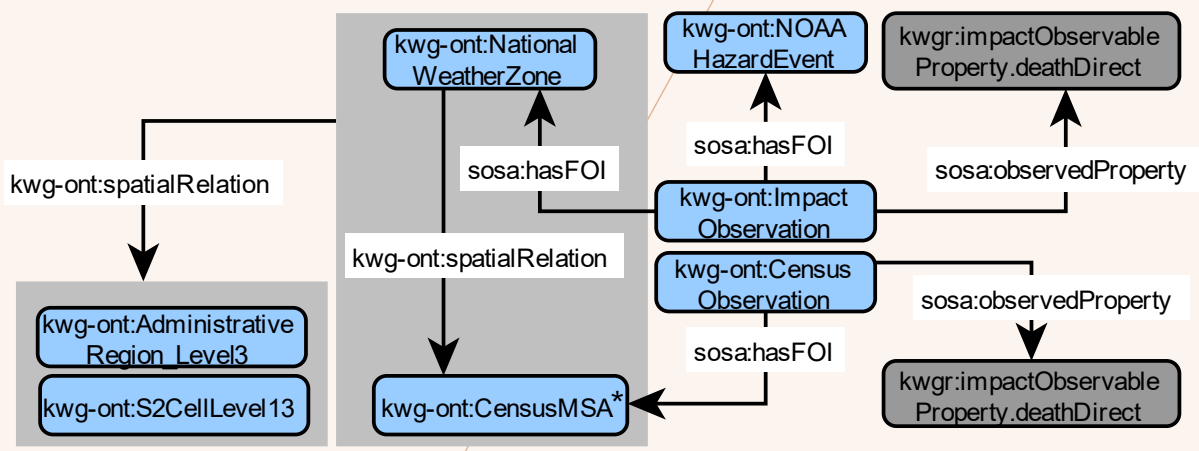
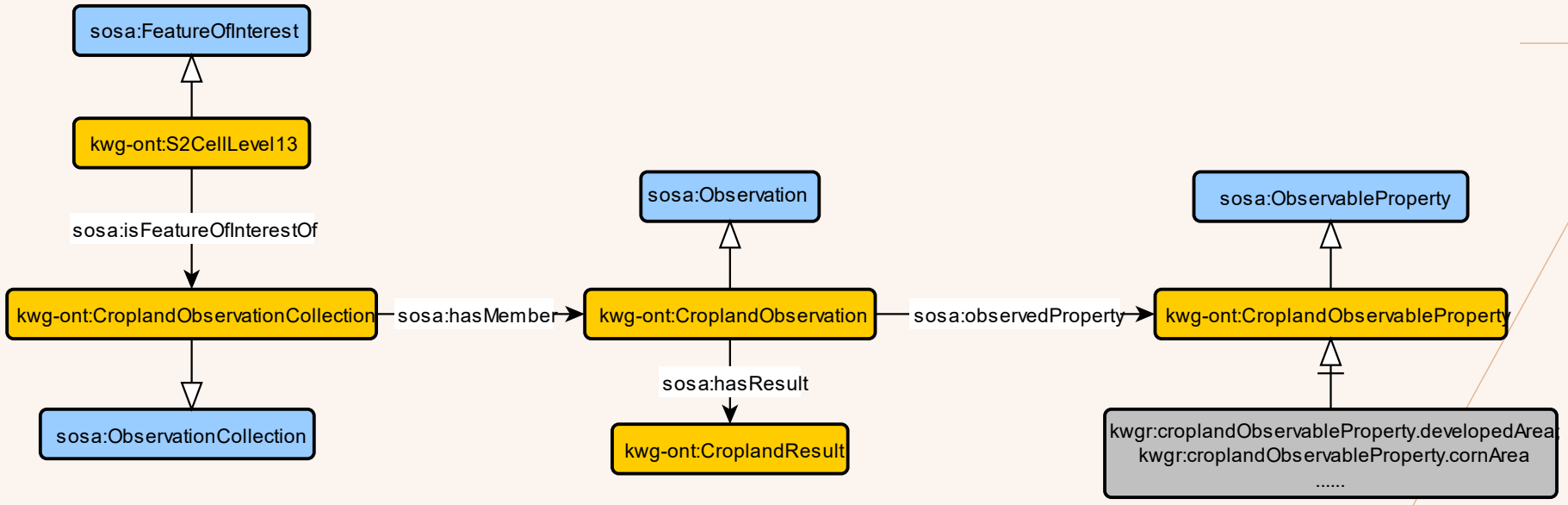


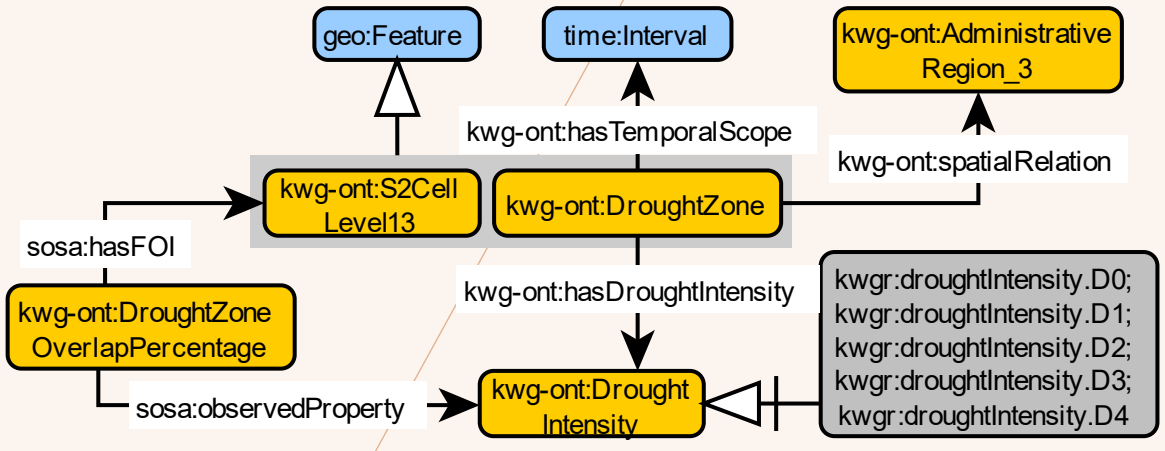


* Census Metropolitan and Micropolitan Areas

MODELING SPATIAL AGGREGATES



Consider the scalability of the ontology to accommodate large datasets and complex spatial queries efficiently



KNOWING WHERE VIA KNOWLEDGE GRAPH-BASED GEO-ENRICHMENT

DOMAIN ONTOLOGIES AND PATTERNS IN KNOWWHEREGRAPH

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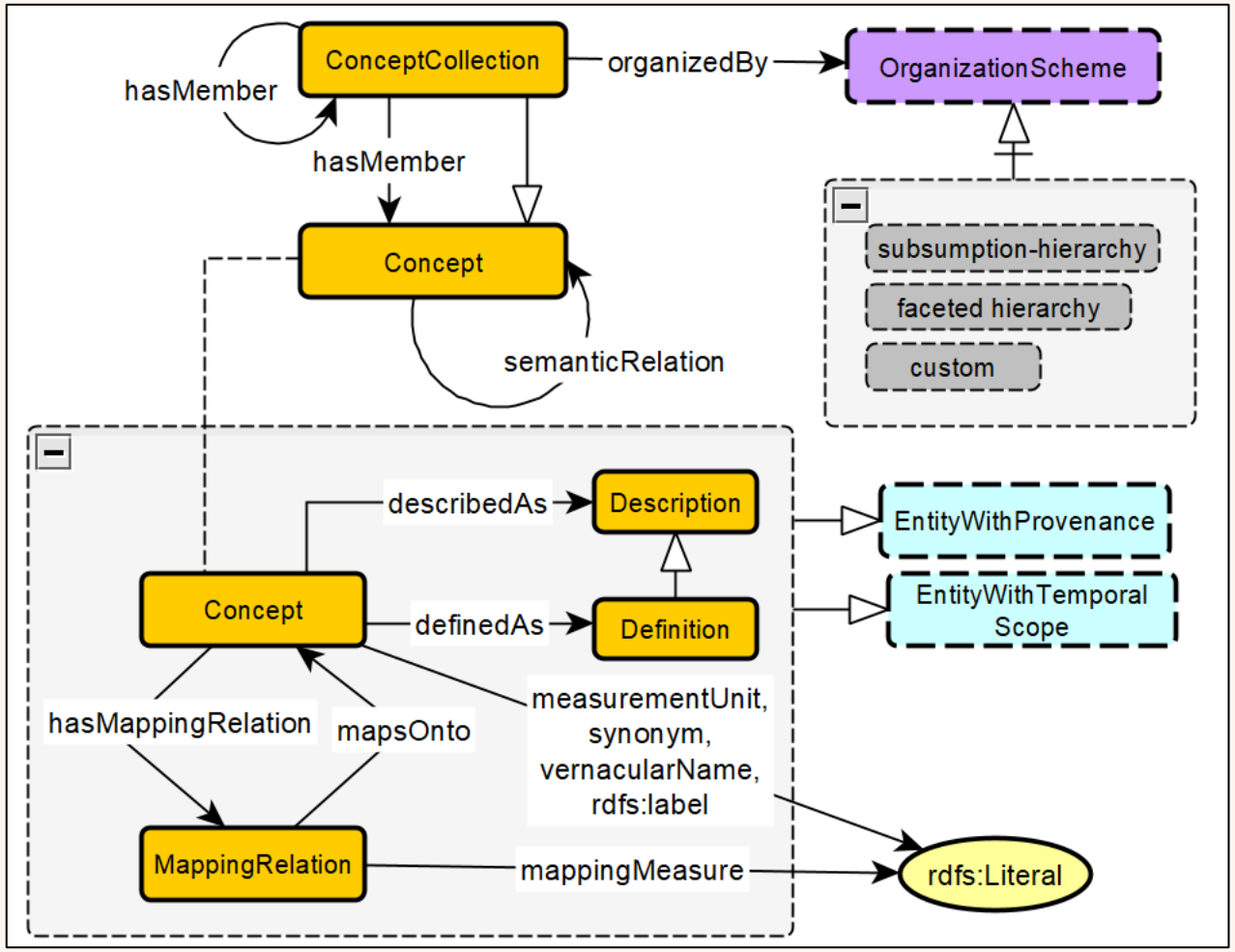
THE KNOWWHEREGRAPH ONTOLOGY

The KnowWhereGraph is

- one singular ontology,
- that represents a myriad of domains,
- by leveraging several ontology design patterns and domain ontologies (utilizing the Modular Ontology Methodology (MOMo),
- and can integrate more.

THE SCIENTIFIC TAXONOMY PATTERN (STP)



An ontology design pattern for modeling a scientific taxonomy as an ontology.

Stephen, S., Shimizu, C., Schildhauer, M., Zhu, R., Janowicz, K., & Hitzler, P. (2022). A Pattern for Representing Scientific Taxonomies.

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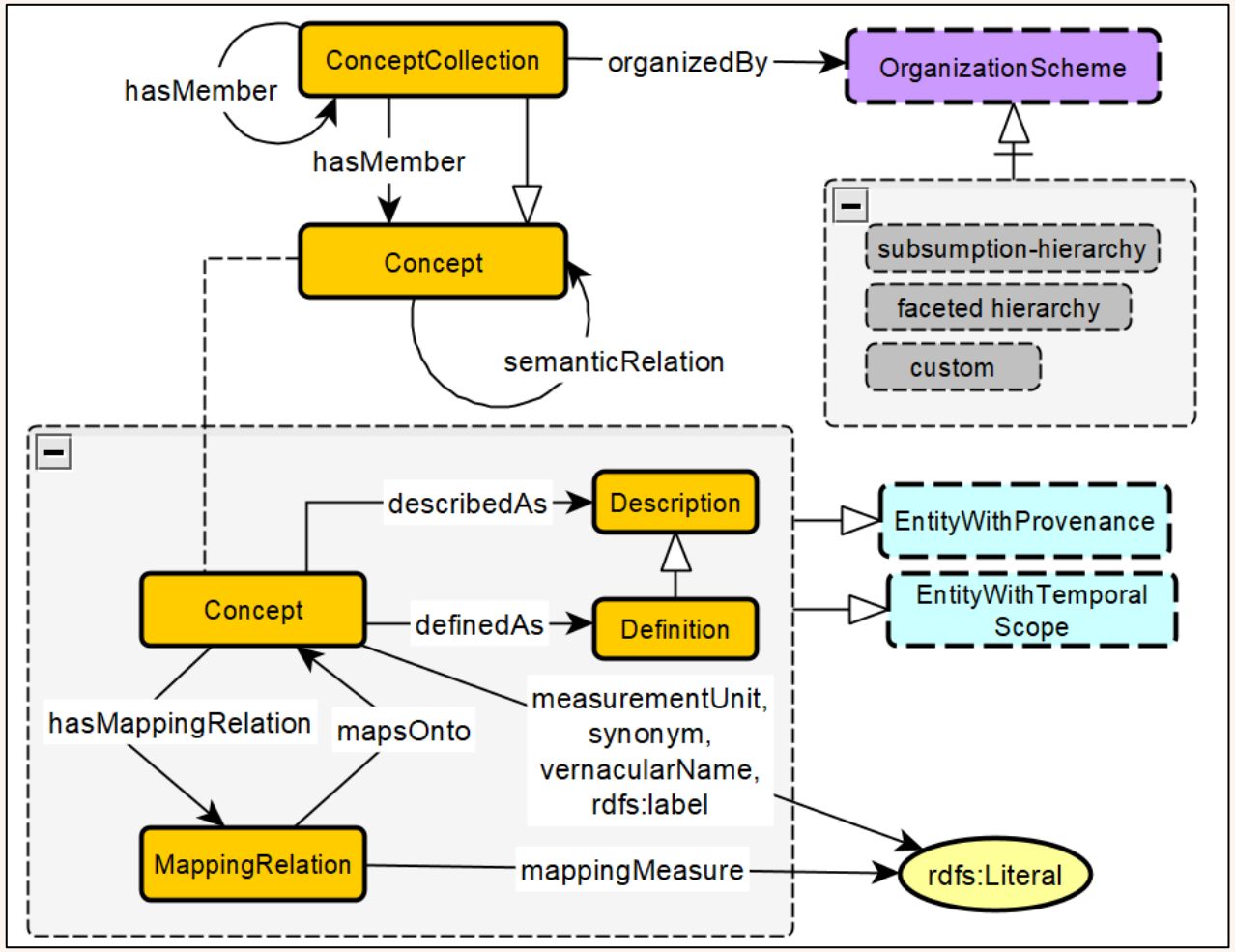

1) capture **temporal dynamics** of concepts as taxonomies evolve,
2) model the **provenance** of concepts to add context and enable governance,
3) assist the translation of **taxonomic relations to ontological relations** appropriately that will empower their use within KGs,
4) tag **provenance** and other metadata information to **mappings** or alignments of uncertainty between concepts in different ontologies

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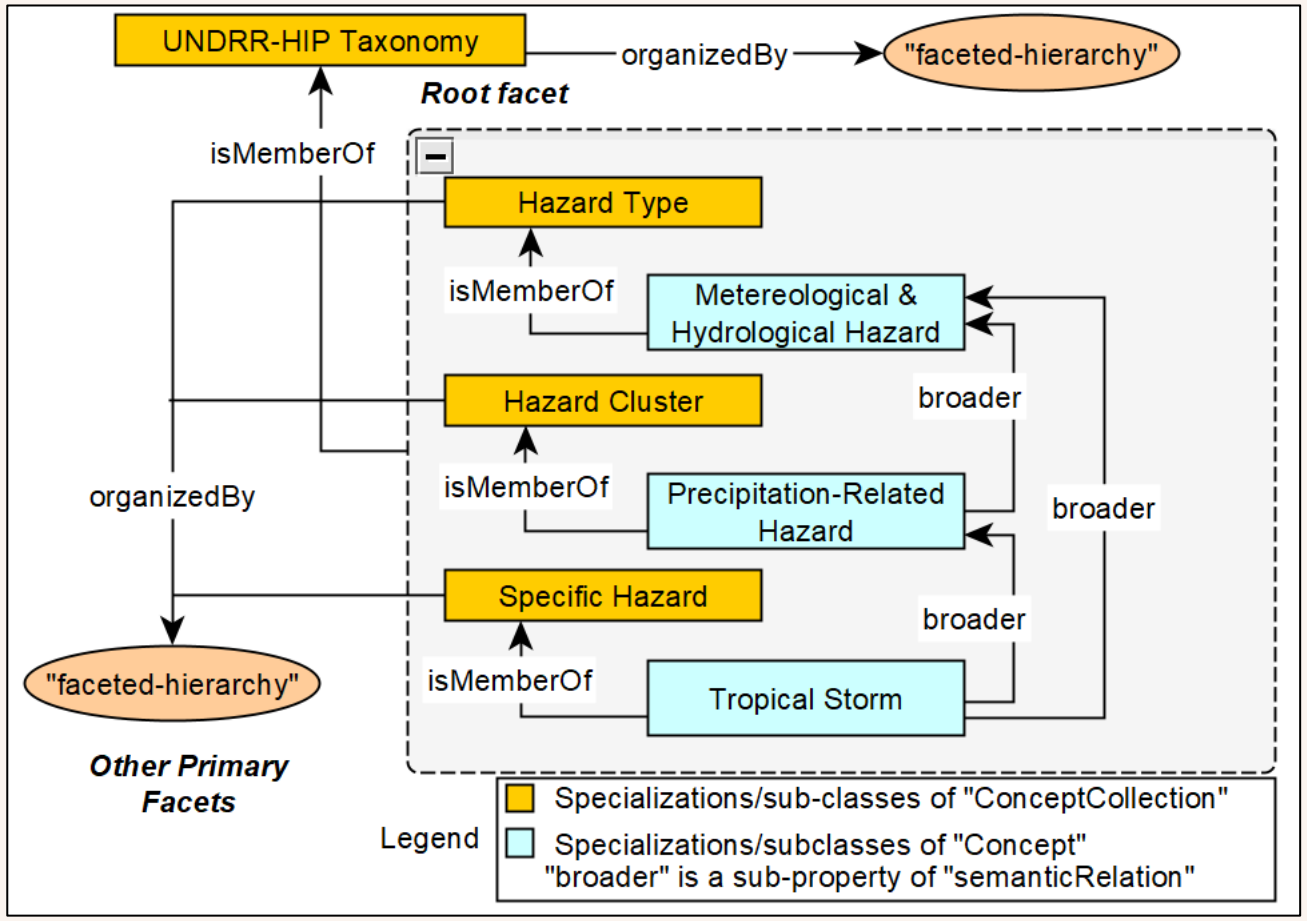
THE SCIENTIFIC TAXONOMY PATTERN –AN EXAMPLE



Structure of UNDRR's HIP represented using STP

1) The HIP taxonomy is a harmonized hazard typology developed by UNDRR
2) **Multi-dimensional** (or multi-faceted), with concepts across three different facets semantically and meaningfully inter-linked
3) Contains **metadata** information: hazard name, reference number, definition(s), synonyms, scientific description, globally used metrics and numeric limits, references to key relevant UN conventions or multilateral treaties, coordination agency or organization that provided technical guidance on the hazard etc.

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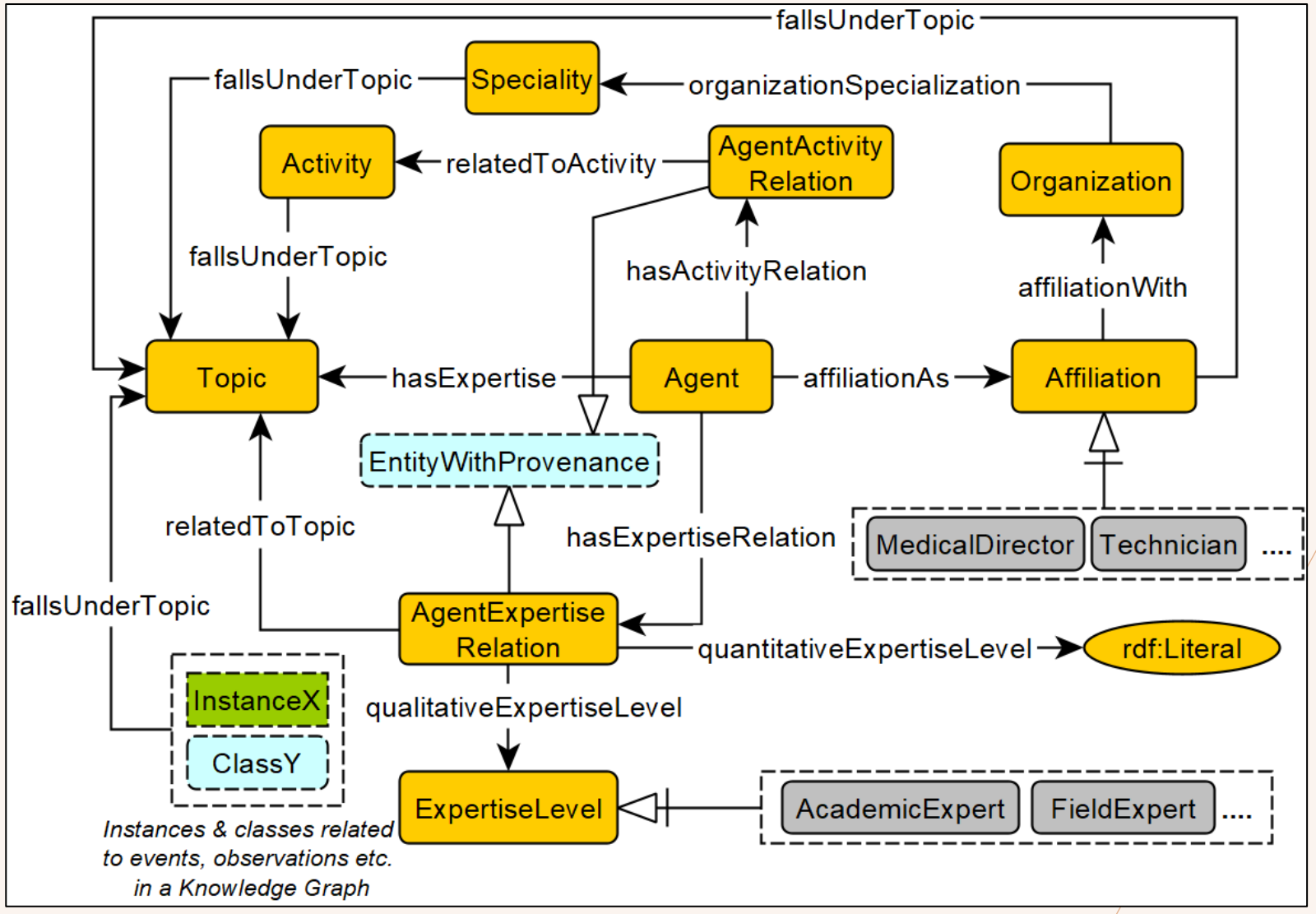
THE EXPERTISE ONTOLOGY



Synthesizes three different ways to characterize an expert, based on:

a) an identifiable academic expertise

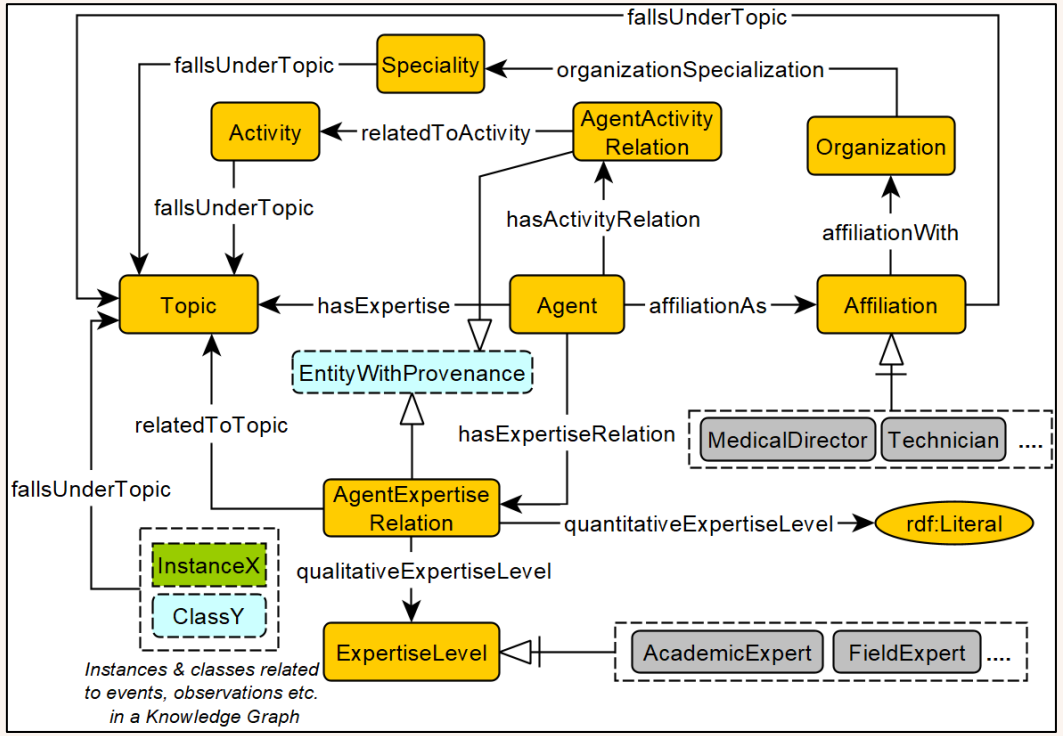
b) voluntary engagements, work-related responsibilities or experience

c) organization specializations or affiliations

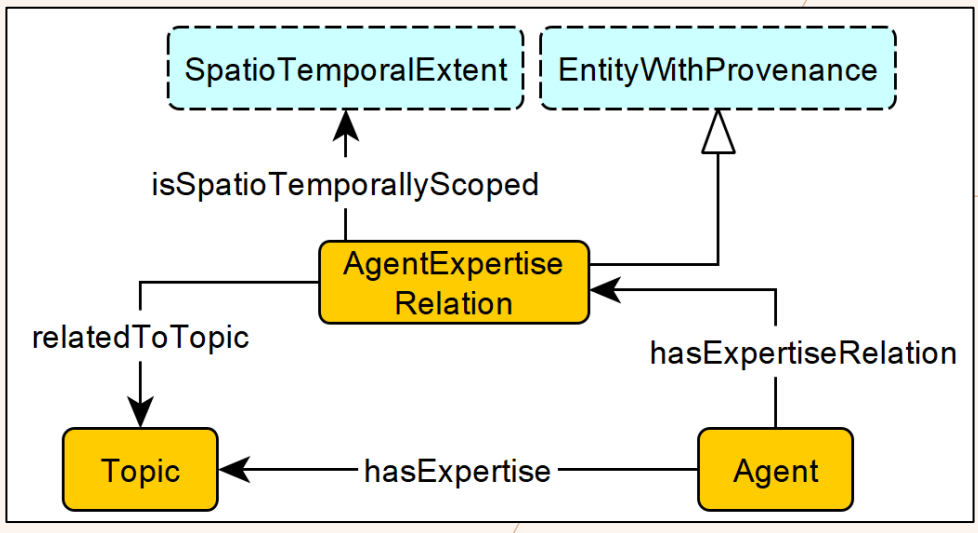
Stephen, S., Schildhauer, M., Cai, L et al. (2023). The Expertise Ontology: Modeling Expertise in the Context of Emergency Management. Formal Ontologies In Information Science 2023, Quebec, Canada.

THE EXPERTISE ONTOLOGY

- Modeling topic and asserting expertise



The reified expertise relation



AgentExpertiseRelation: Primarily to model experts from the academic or broader scientific community whose expertise can be determined from their publication history

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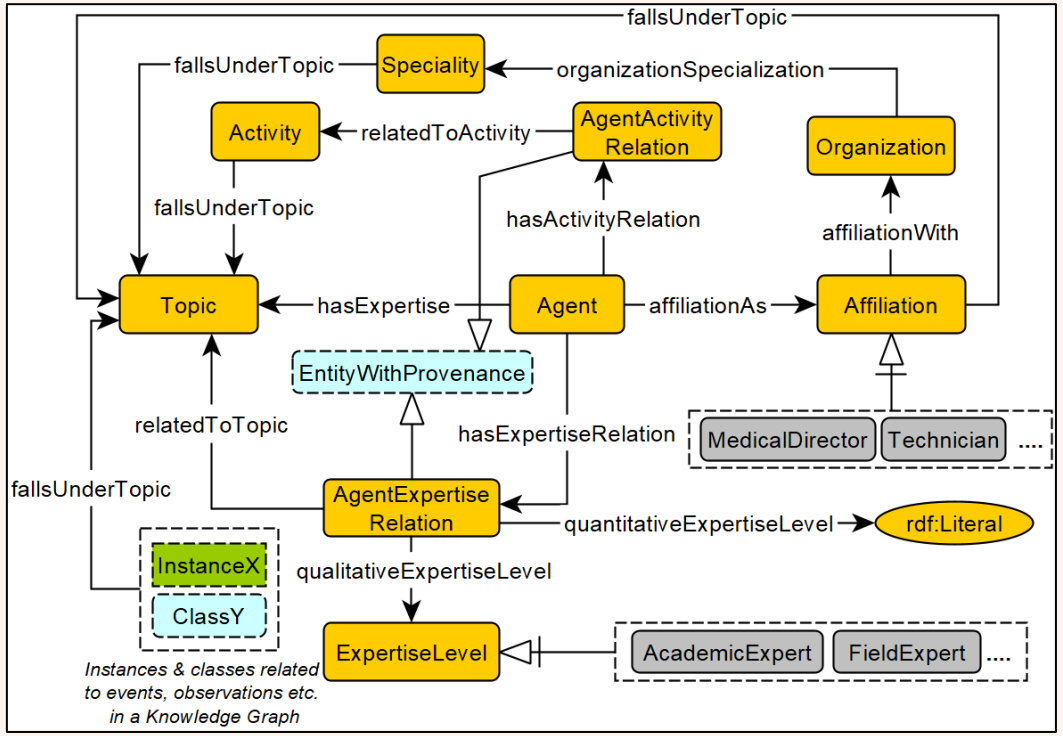

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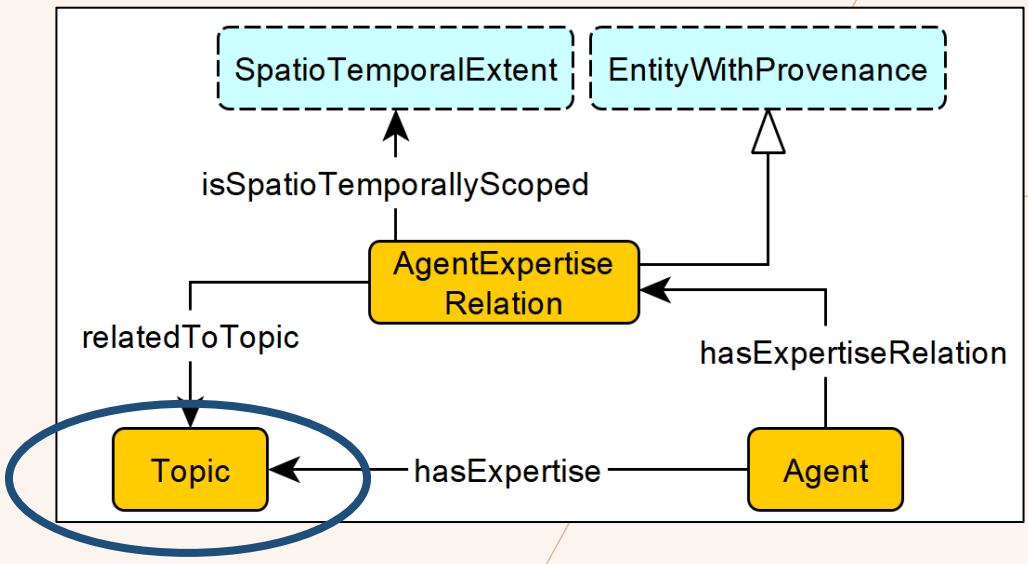
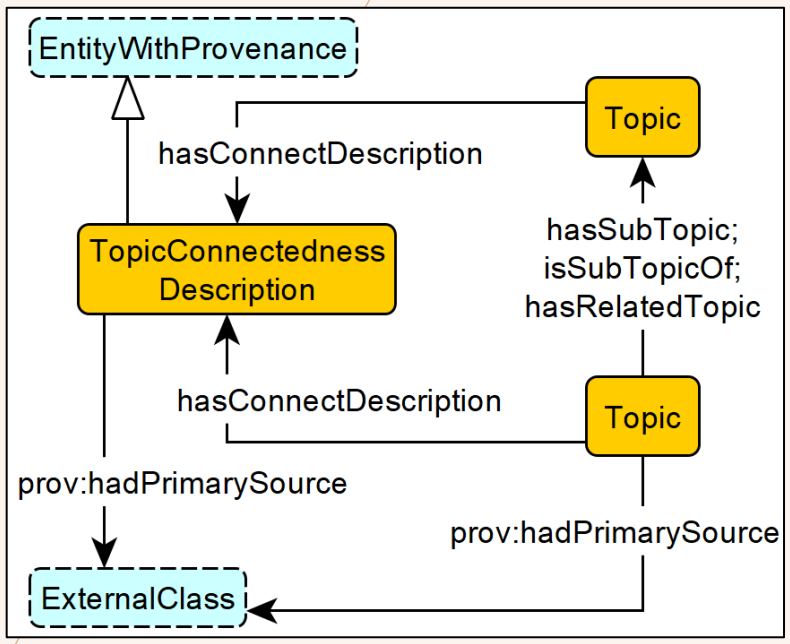


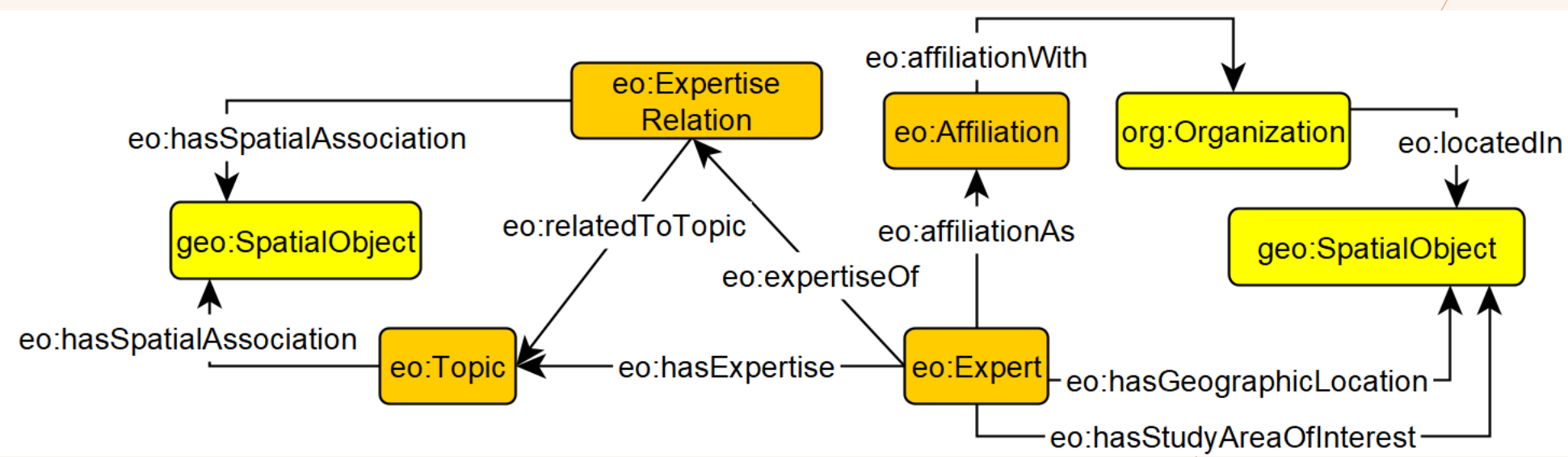


Modeling topics (from UNDRR, DO etc.) using STP

THE EXPERTISE ONTOLOGY

- Spatio-temporally scoping expertise

Spatial scoping



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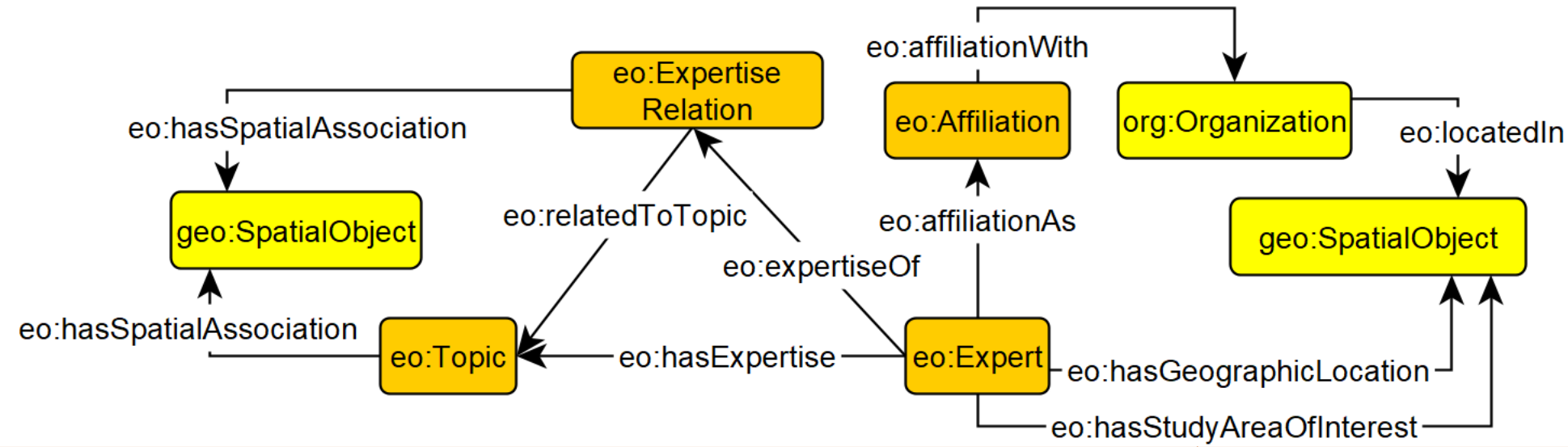
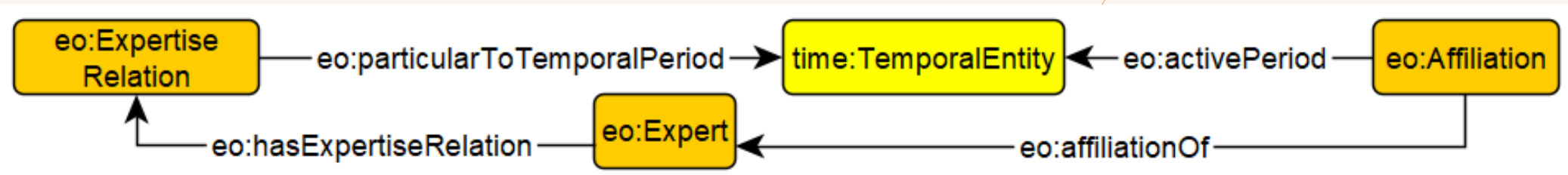


Temporal scoping



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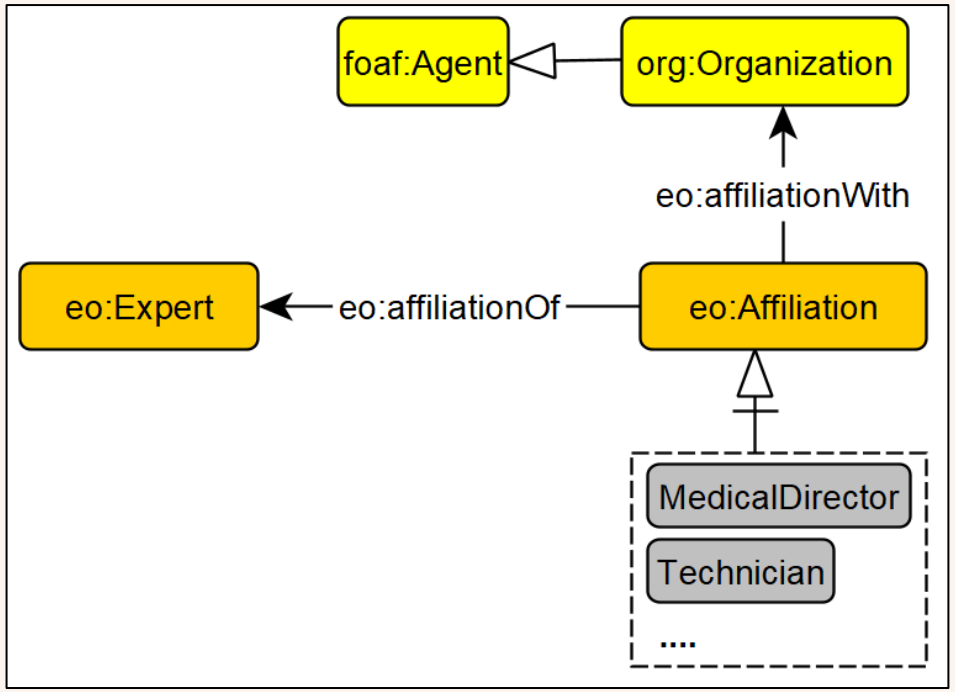
THE EXPERTISE ONTOLOGY

- Organization specializations/affiliations



Affiliation: To assert expert based on their job role or organization affiliation. E.g., a health professional's affiliation as a program director or a trauma surgeon within a hospital.

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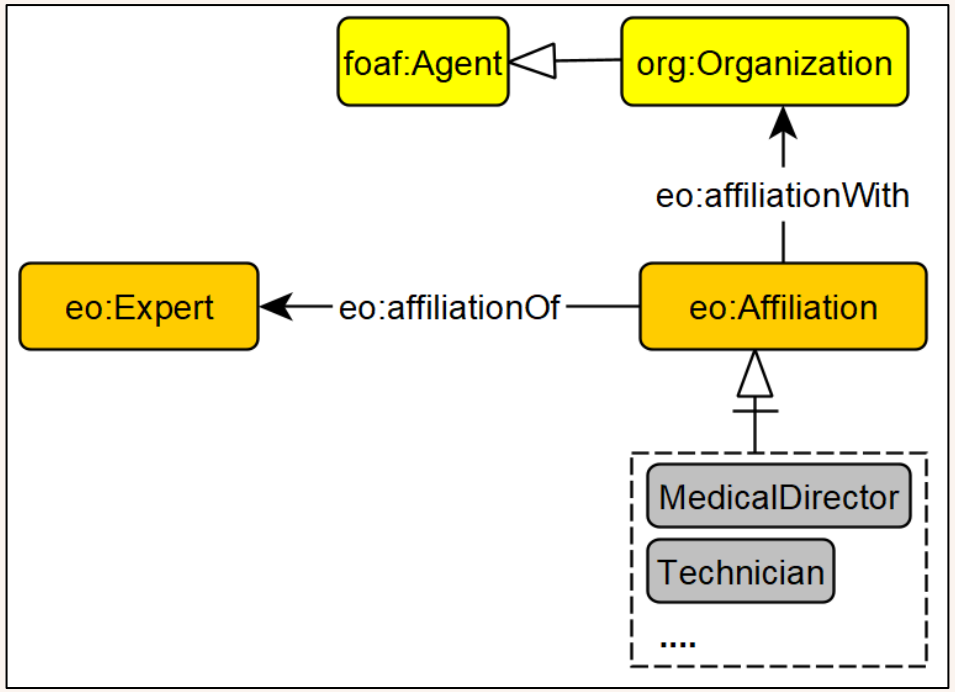
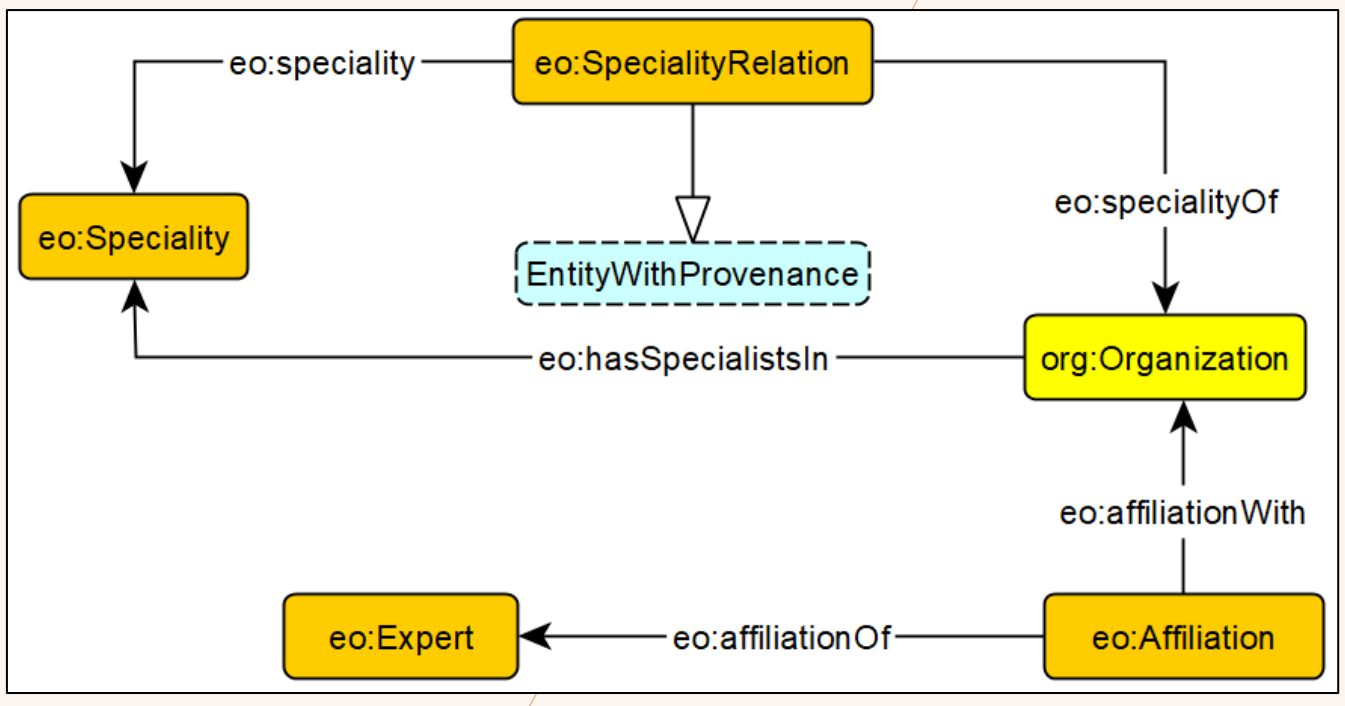


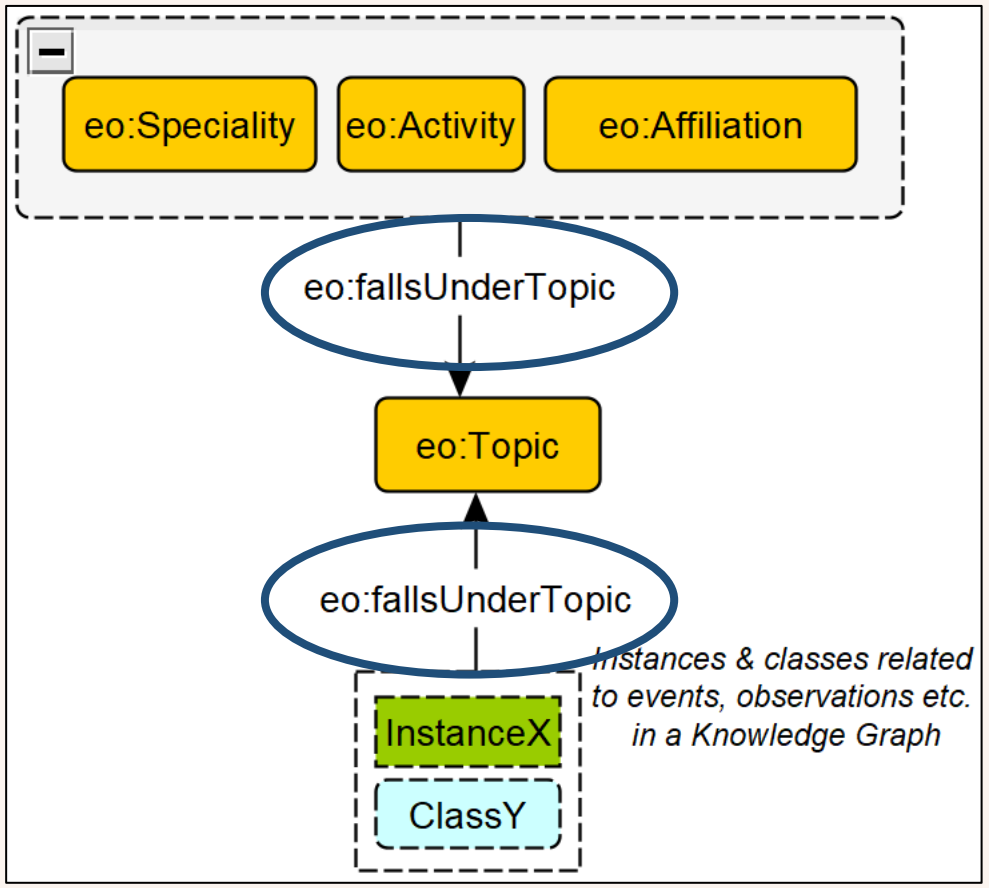


Affiliation: To assert expert based on their job role or organization affiliation. E.g., a health professional's affiliation as a program director or a trauma surgeon within a hospital.

SpecialityRelation: To assert experts based on activity-oriented facts, such as job performance assessments or volunteer activities.

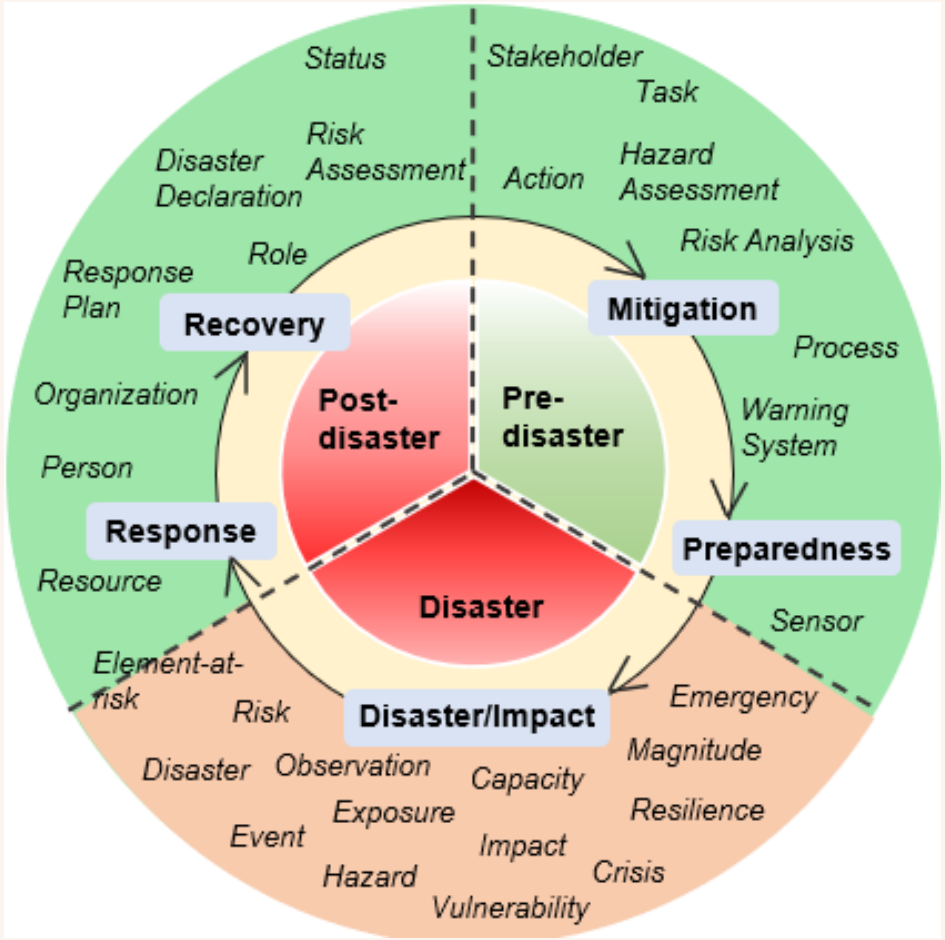
THE EXPERTISE ONTOLOGY

- Annotating knowledge graph content with topics



- annotate instances in the graph with relevant topics
  - use different AI techniques to determine similarity between entities
- classes can also be linked to specific topics through punning
- property chain axiom described over *fallsUnderTopic* and *isSubTopicOf* infers relations between these instances/ classes with topics above in the hierarchy.

THE DISASTER MANAGEMENT DOMAIN ONTOLOGY (DMDO)*



Disaster and disaster-management stages as they are conceptualized in traditional disaster life cycle models

* work in progress

DMDO offers

- a consistent knowledge pattern that can be used to query across all hazard datasets (e.g., on droughts, hurricanes, and wildfires) in a uniform manner
- alignment of named events (e.g., *Hurricane Katrina*) across different datasets (e.g., NOAA Storm Events, FEMA Disaster Declarations Summaries, NOAA Historical Hurricane Tracks)
- methods to use or integrate data with authoritative classification schemas and vocabularies; and
- representation of causal relations between events and/or impacts and effects on people, places and public health.

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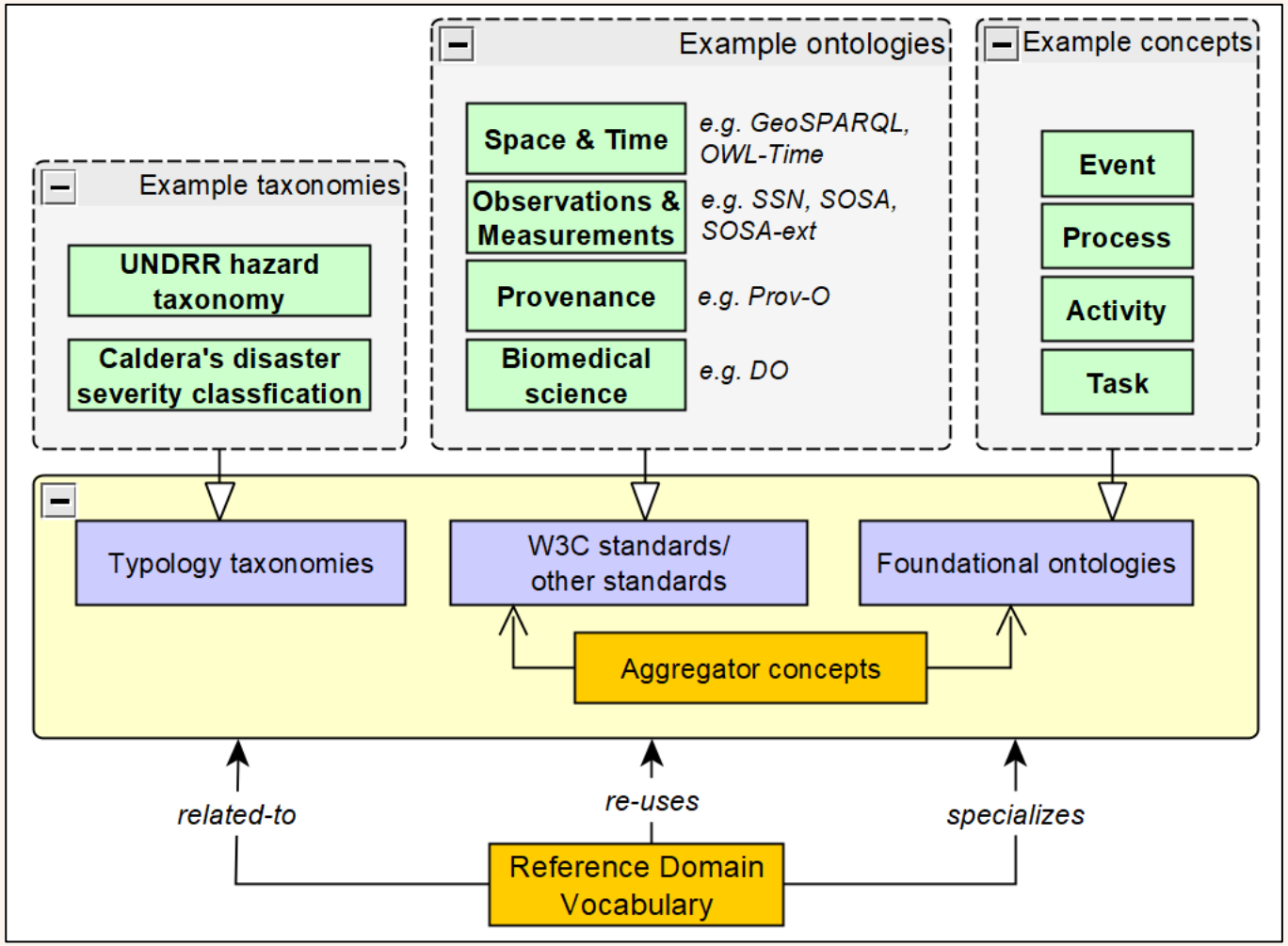

A high-level ontology framework of DMDO

* work in progress

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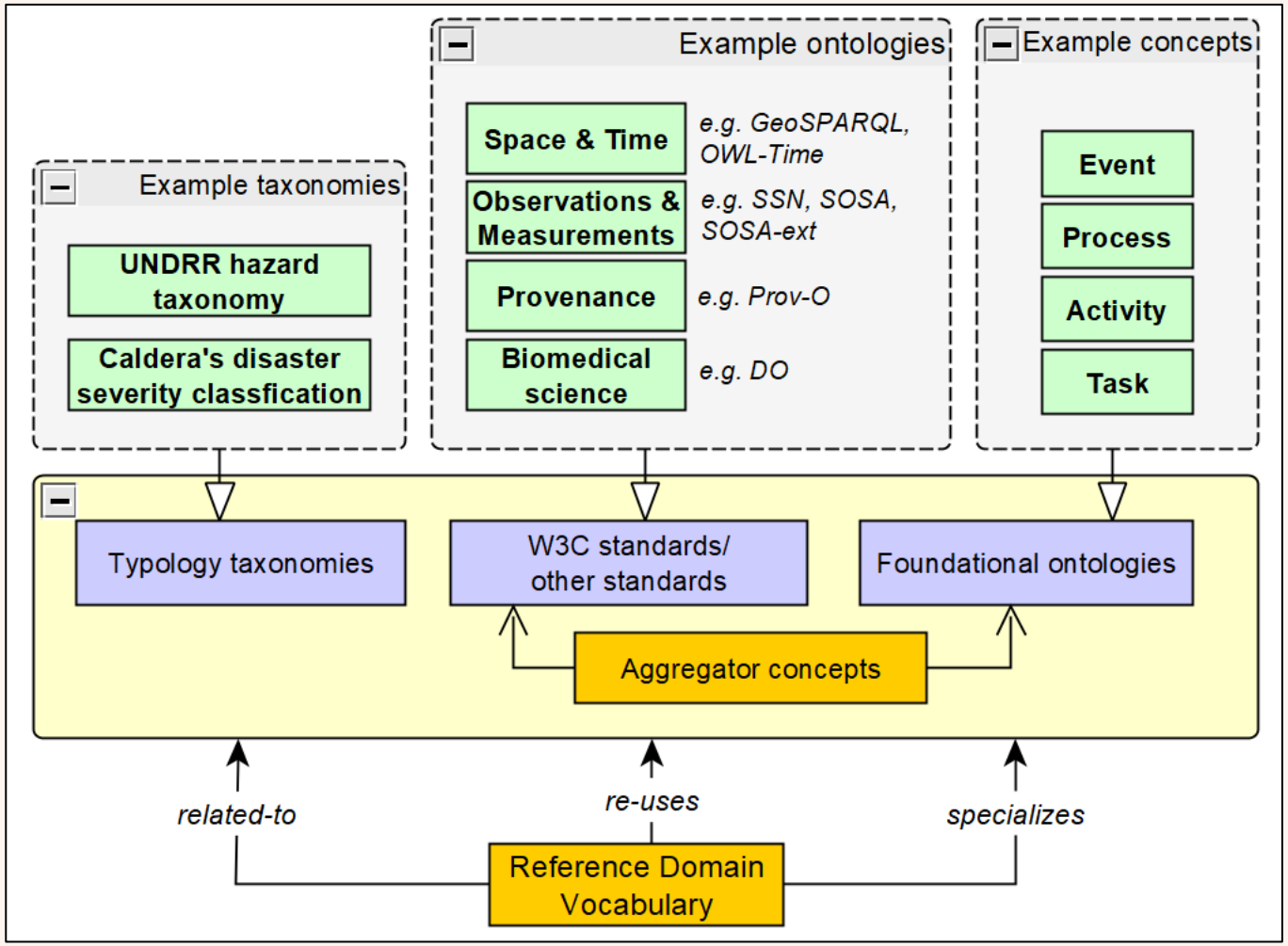

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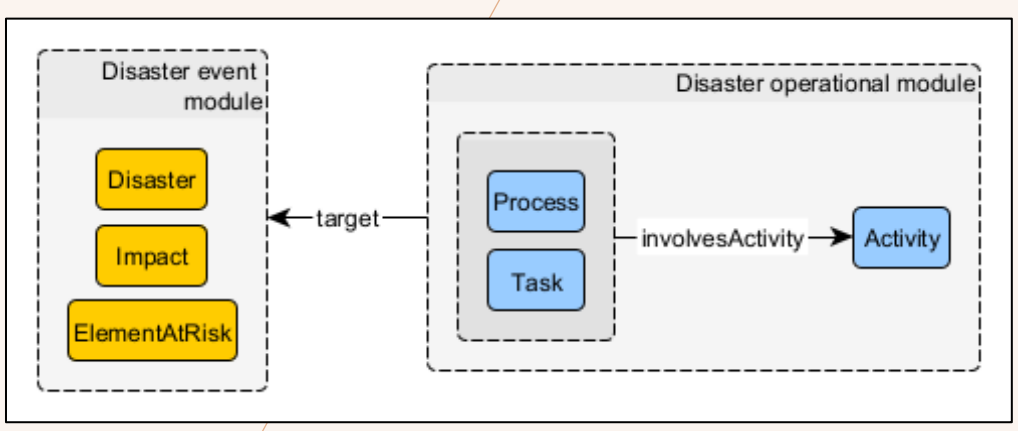

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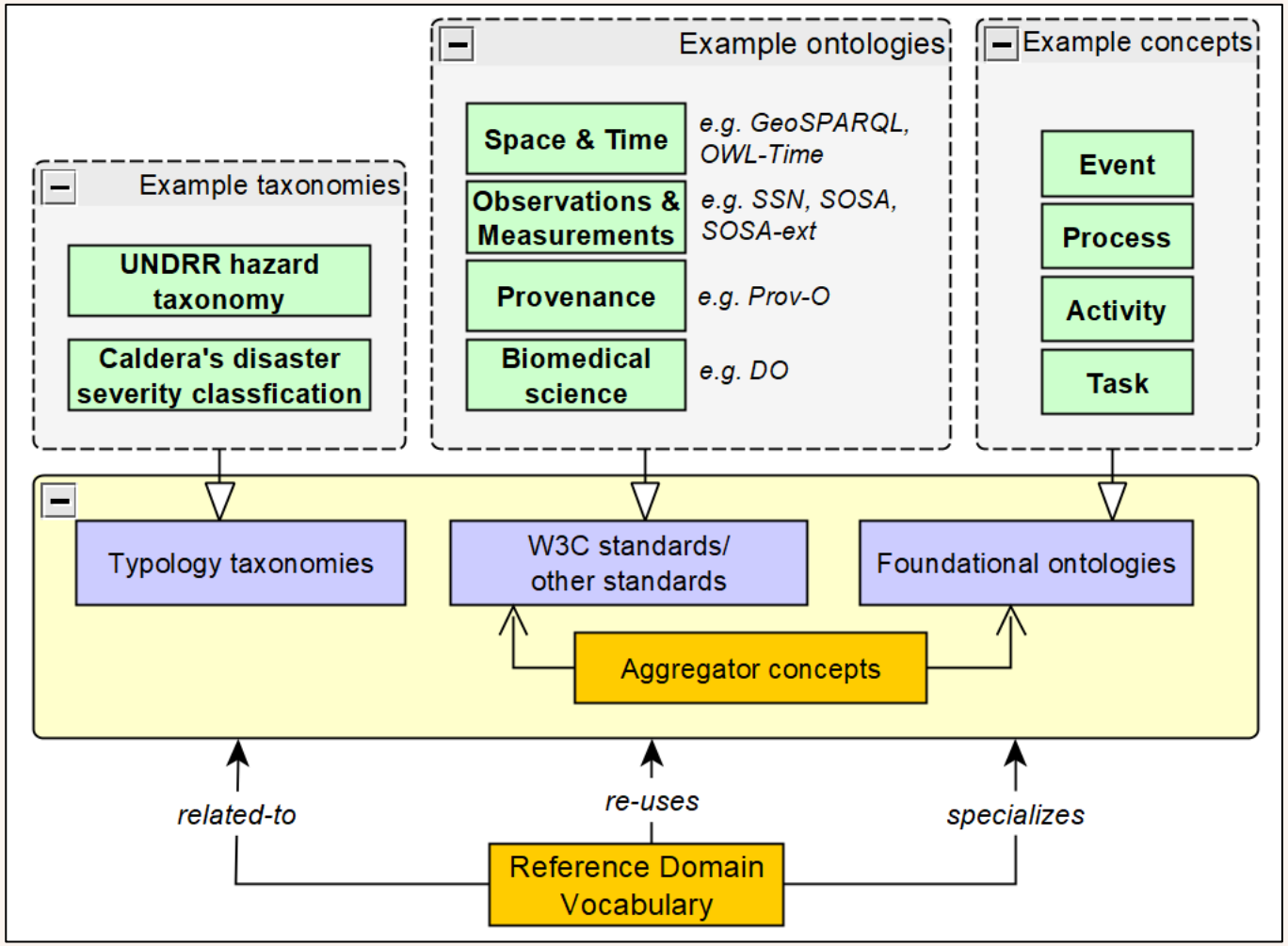

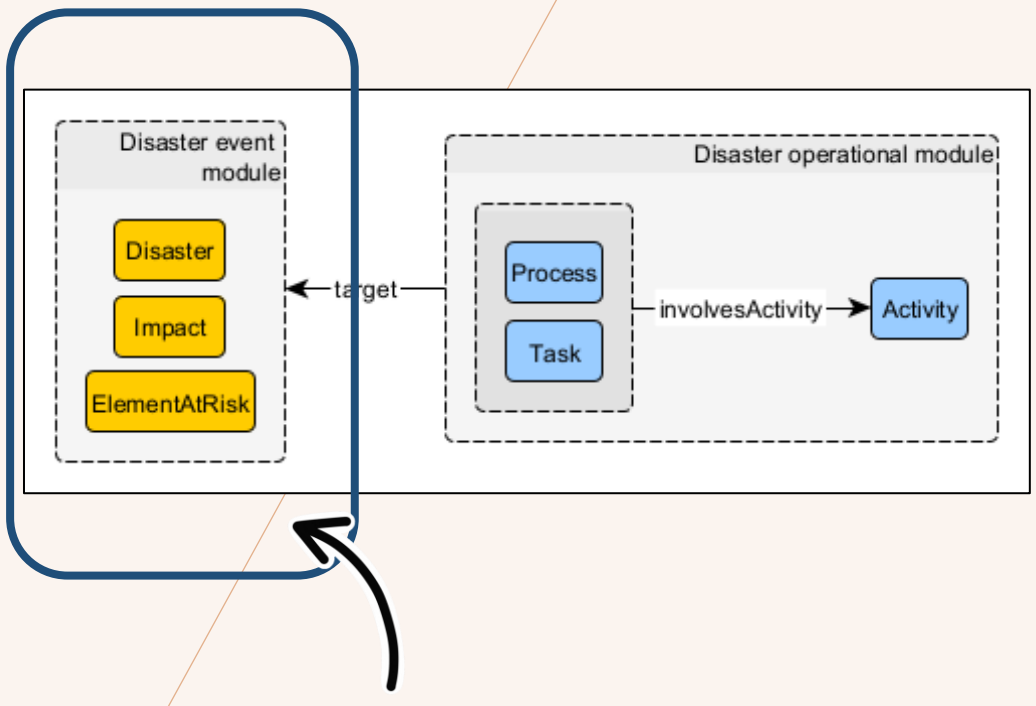

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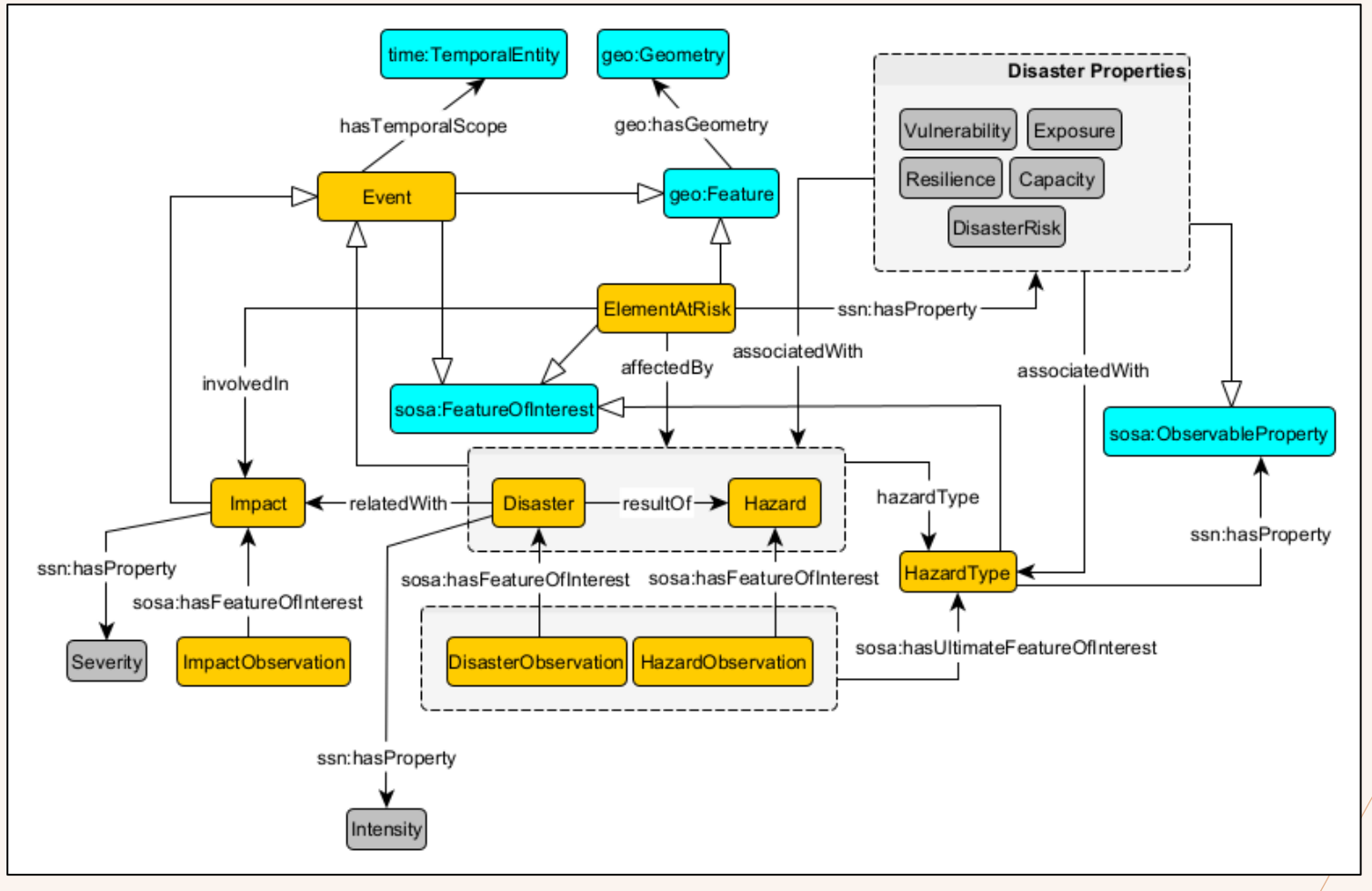
- Module 1: Modeling the interrelationships between Hazard, Disaster, Impact, and ElementAtRisk



The Hazard Event Module, conceptualizes and organizes observational data about different types of hazards, by re-using the **SOSA** and **GeoSPARQL** ontologies

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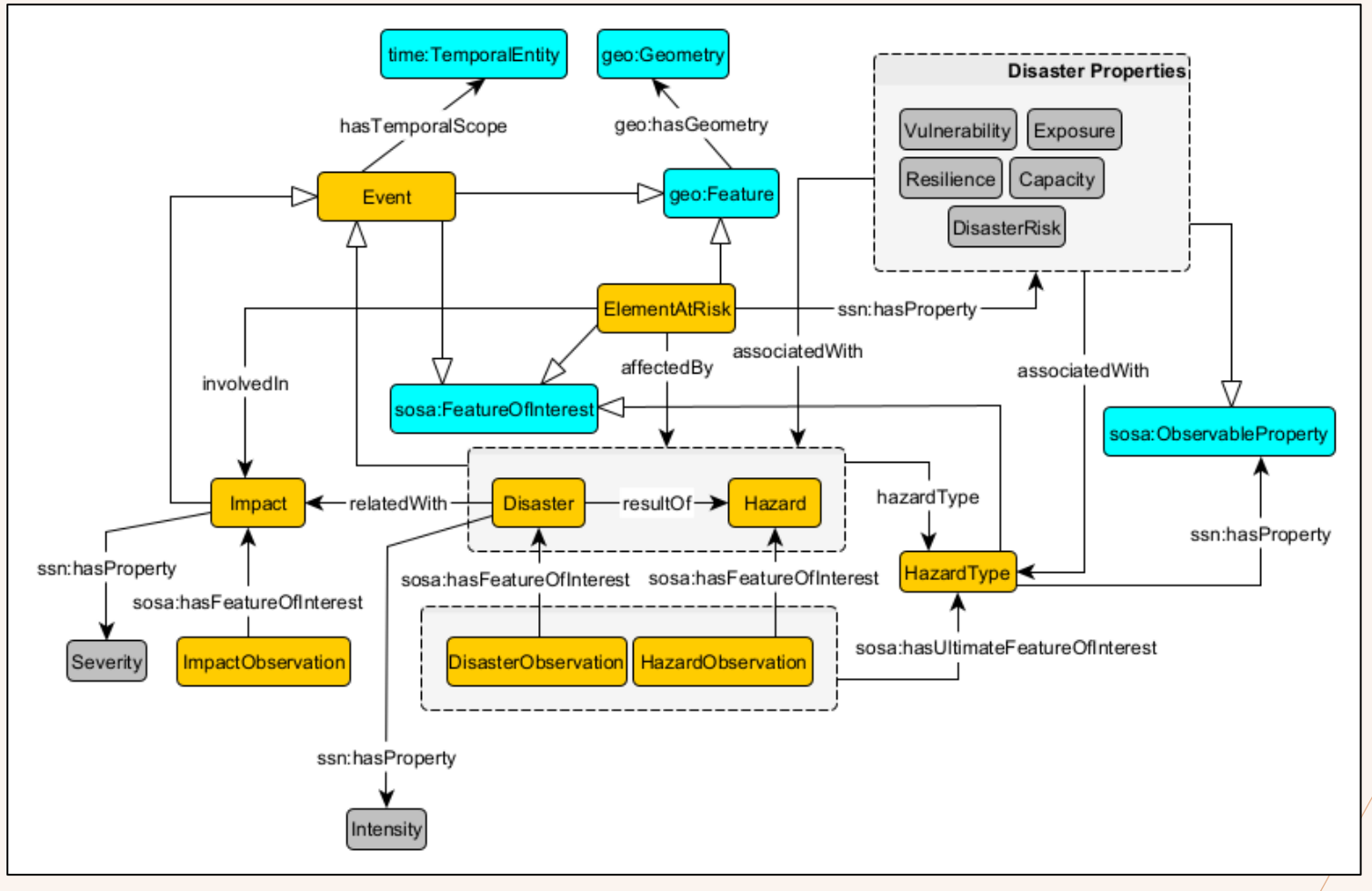
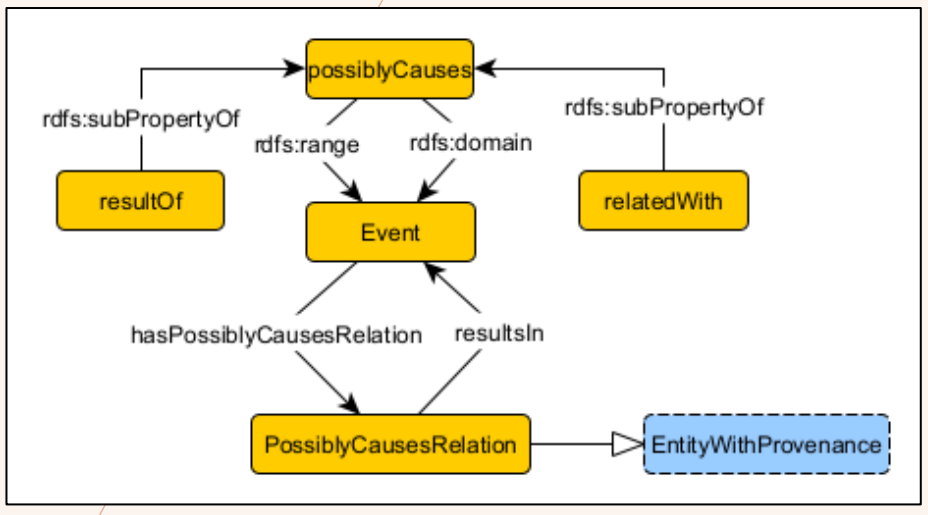
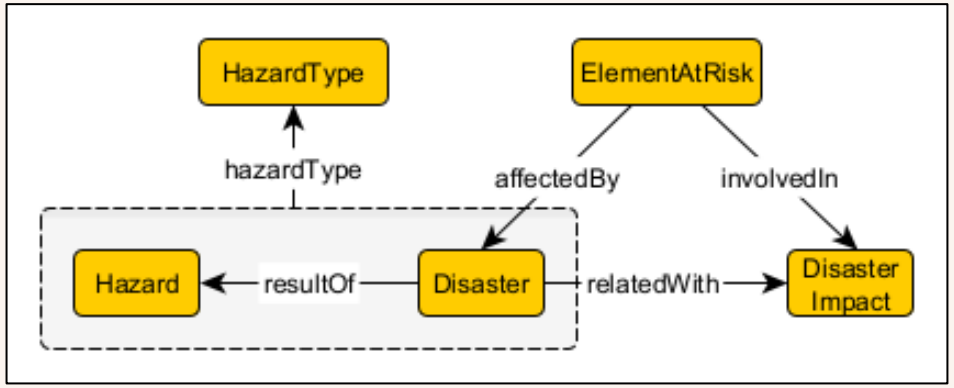




A simple pattern for modeling causal relations between events

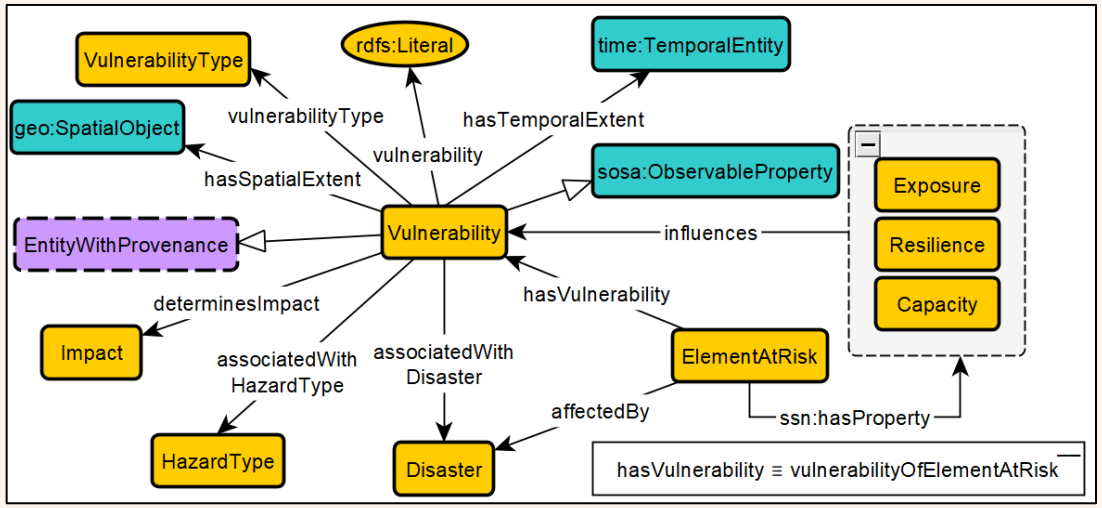
THE DISASTER MANAGEMENT DOMAIN ONTOLOGY (DMDO)*

- Module 2: Modeling properties in the disaster management domain

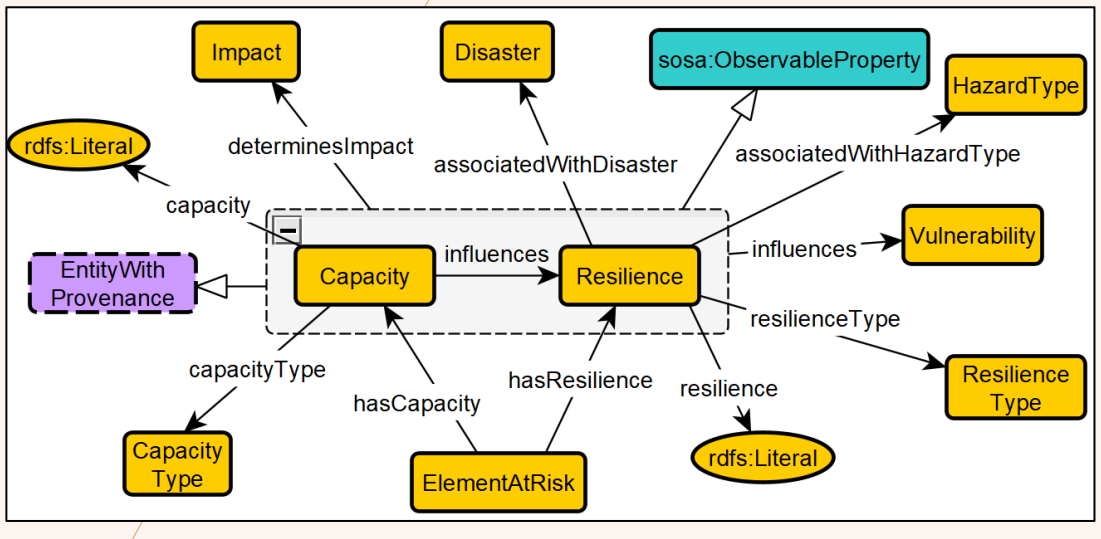


Generalized schema of Module 1

Vulnerability



Capacity and Resilience



Stephen, S., Schildhauer, M., Shimizu, C et al. (2023). The Disaster Properties Ontology. Formal Ontologies In Information Science 2023, Quebec, Canada.

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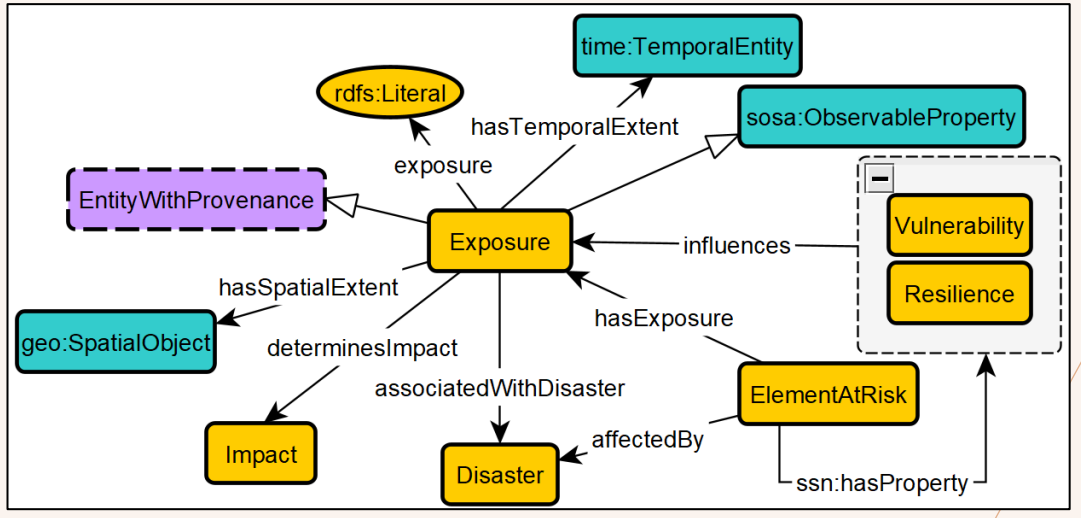
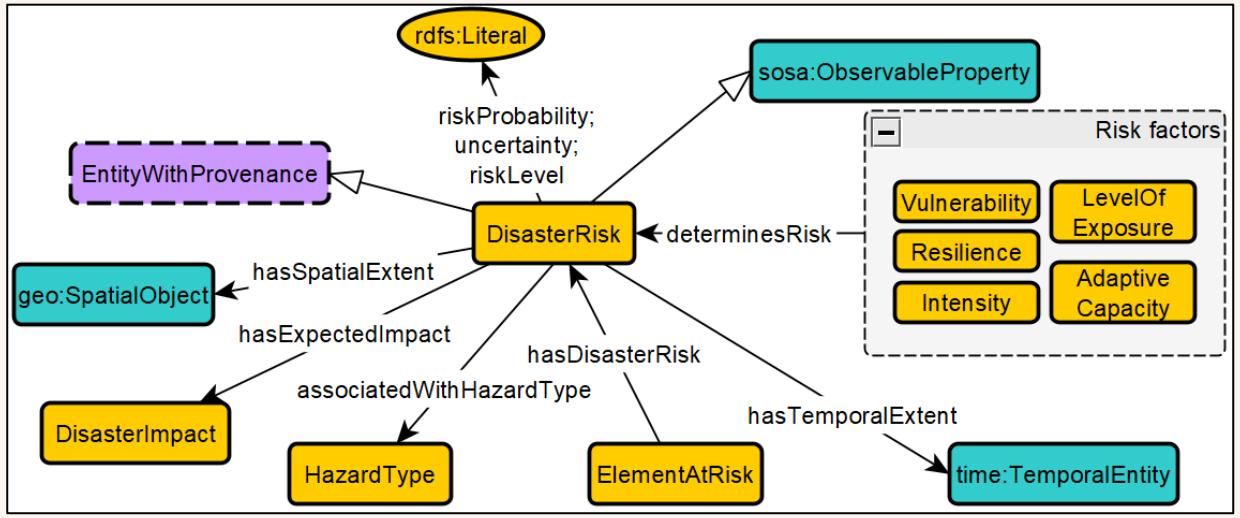
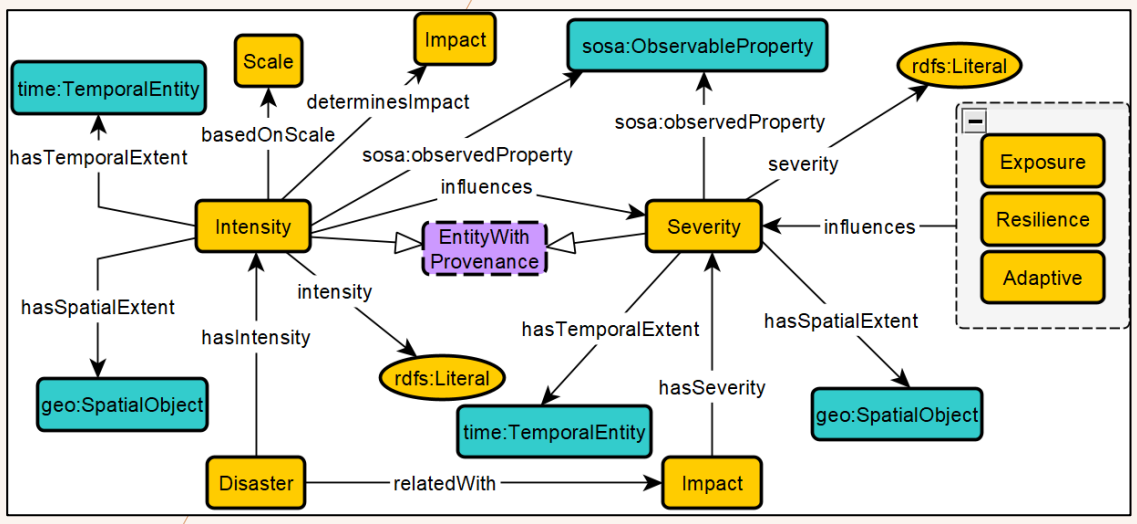


Exposure

Disaster Risk



Intensity and Severity



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CONCLUSION

- A Knowledge Graph connects an ontology to data and/or content
- To explicitly model content and data models, an explicitly modeled ontology is essential to express unambiguous metadata terms and relationships
- The KWG ontology satisfies the following requirements:
  - **enable geospatial integration**
  - **facilitate data integration** by providing an overarching framework for the semantic harmonization of key terms and concepts.
  - **provide rich inferencing** to infer latent relationships between datasets, such as the causality of events
  - **highly maintainable** in terms of facilitating data integration, schema modification, and expansion