

# Introduction to Patterns & Modules

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## Knowledge Engineering

Broadly Defined

## Open Science

Linking Artifacts, Workflows, and Assisting  
Research

## Effective Pedagogy

Methods for Individualized Teaching and  
Examination



# Outline & Objectives

Motivation

Modular Ontology Modeling

Examples

Tools & Resources

# Example: The KnowWhereGraph

## The KnowWhereGraph

Funded by NSF, as part of the convergence accelerator program, worth \$6M, over 50 collaborators

Incorporates over 30+ thematic and “placial” datasets into a knowledge graph with over 13.5 billion triples

We can integrate data over different geospatial representations to derive key insights and summarize them into area briefings

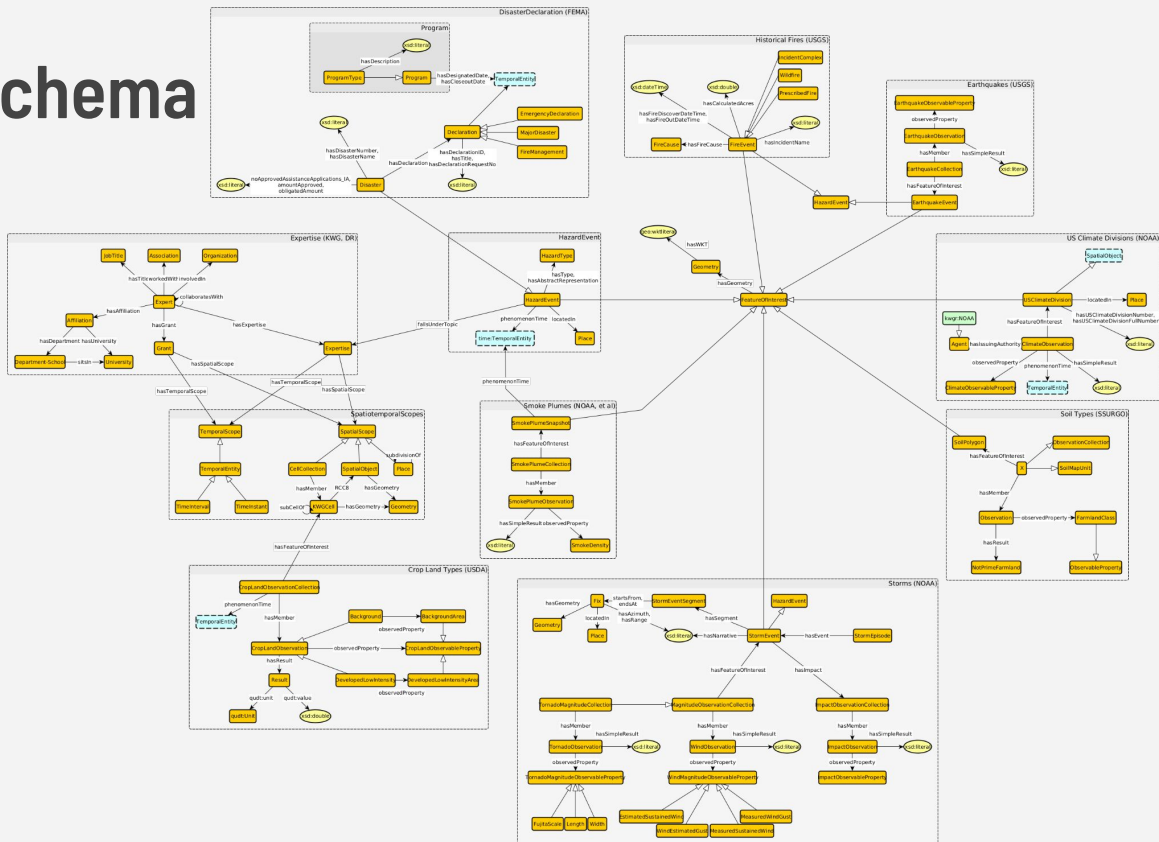


| Thematic Datasets             |                           |                                                                       |                           |                             | Place-Centric Datasets            |                                                                                                                         |                                                |
|-------------------------------|---------------------------|-----------------------------------------------------------------------|---------------------------|-----------------------------|-----------------------------------|-------------------------------------------------------------------------------------------------------------------------|------------------------------------------------|
| Dataset Name/<br>Theme        | Source<br>Agency          | Key Attributes                                                        | Spatial<br>Coverage       | Temporal<br>Coverage        | Place-Centric<br>Dataset          | Defining<br>Authority                                                                                                   | Spatial<br>Coverage                            |
| Soil Properties               | USDA                      | soil type, farmland class                                             | Targeted<br>regions in US | Current                     | S2 Cells                          | Google                                                                                                                  | Lvl 9 (Global),<br>Lvl 11 (US),<br>Lvl 14 (CA) |
| Wildfires                     | USGS, USDA,<br>USFS, NIFC | wildfire type, burn severity,<br>num. acres burned,<br>contained date | US                        | 1984–current                | Global<br>Administrative<br>Areas | University of<br>Berkeley,<br>Museum of<br>Vertebrate<br>Zoology and the<br>International<br>Rice Research<br>Institute | Global                                         |
| Earthquakes                   | USGS                      | magnitude, length, width,<br>geometry                                 | Global (mag.<br>over 4.5) | 2011-01-01 to<br>2021-02-10 |                                   |                                                                                                                         |                                                |
| Climate Hazards               | NOAA                      | injuries, deaths, property<br>damages                                 | US                        | 1950–2020                   |                                   |                                                                                                                         |                                                |
| Expert - Covid-19<br>Mobility | Direct Relief<br>(DR)     | name, affiliation, expertise                                          | Global                    | 2021                        | US Federal<br>Judicial District   | DoJ, ESRI                                                                                                               | US                                             |
| Expert - General              | KWG, UC<br>System, DR     | name, affiliation, expertise<br>with spatiotemporal scopes            | Global                    | unlimited                   | CodesNational<br>Weather Zones    | NOAA                                                                                                                    | US                                             |
| Cropland Types                | USDA                      | crop types (raster data)                                              | CA (US)                   | 2020                        | FIPS Codes                        | NRCS                                                                                                                    | US                                             |
| Air Qual. Obs.                | U.S. EPA                  | AQI value, CO concentration                                           | US                        | 1980–2021                   | DMA                               | Nielen                                                                                                                  | US                                             |
| Smoke Plumes                  | NOAA                      | daily smoke plumes extent                                             | US                        | 2010-2021                   | ZIP                               | ZCTA                                                                                                                    | US                                             |
| Climate<br>Observations       | NOAA                      | temperature, precipitation,<br>PDSI, PHSI                             | US                        | 1950 - 2020                 | Climate Division                  | NOAA                                                                                                                    | US                                             |

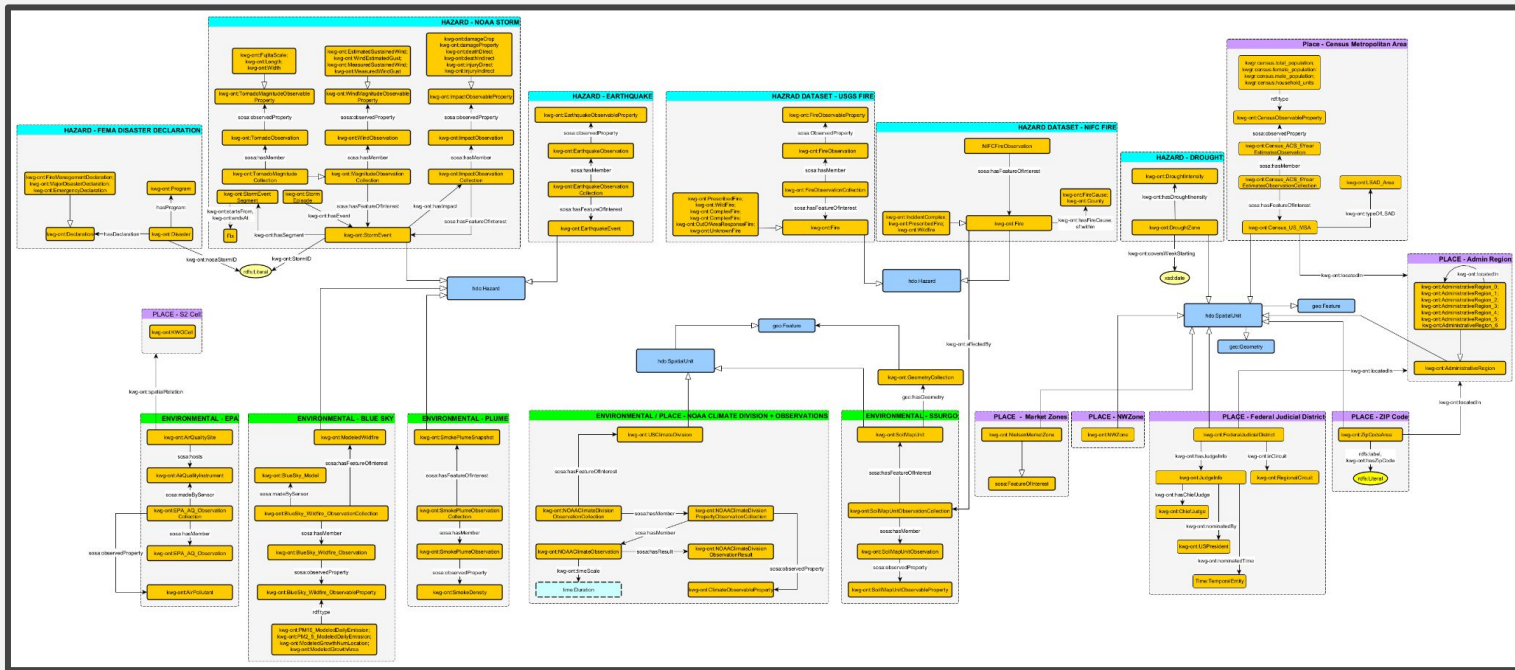
# KnowWhereGraph Schema

Isolate instantiated patterns into modules, and then interconnect them.

Different datasets are given their own modules, as well as conceptually distinct notions, such as Event, which occurs across nearly every dataset.



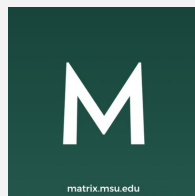
# KnowWhereGraph Schema



Evolution and Maintenance of the graph by replacing modules in the schema. To be explained :)

# Example: The Enslaved Hub

Enslaved | Peoples of the  
Historical Slave Trade



Washington Post

## The Enslaved Hub

- Funded by the Andrew W. Mellon Foundation
- Integrates historical data on enslaved peoples in order to form coherent histories
- The Enslaved Ontology guides the design of a customized Wikibase installation, as well as a data interchange format between historians
- ~1 Million Records

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# Knowledge Engineering *Now with PATTERNS*

Enhancing the field with so-called “pattern-mediated methods” for improved reusability

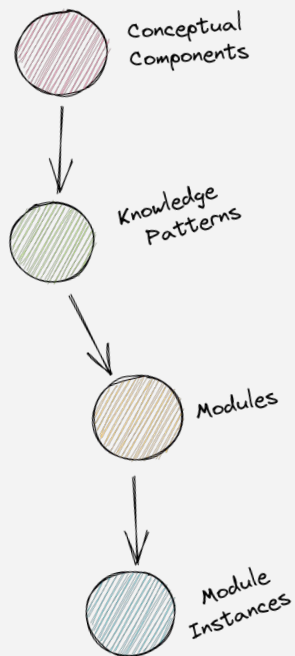
## **Patterns + Schemas = Modularity**

Modular KG Schemas closely tie human conceptualization to a machine-parseable constraint language. A plug and play mentality allows for the rapid, iterative assembly of schemas using peer-reviewed resources and best practices

## **Metadata Scaffolding**

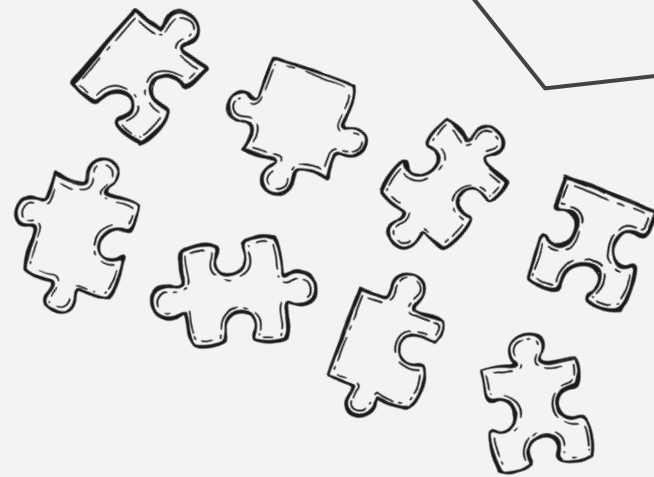
A schema imposes structure on data, encoding knowledge. This *metadata scaffolding* can be used to inform other methods as background knowledge, improving alignment and learning tasks, and provide a mechanism for improved reusability

# Metadata Scaffolding



The scaffolding allows us to quickly:

- assemble modules into an initial schema (like puzzle pieces);
- maintain, evolve, and extend the schema; and
- improve discoverability and navigation of the data



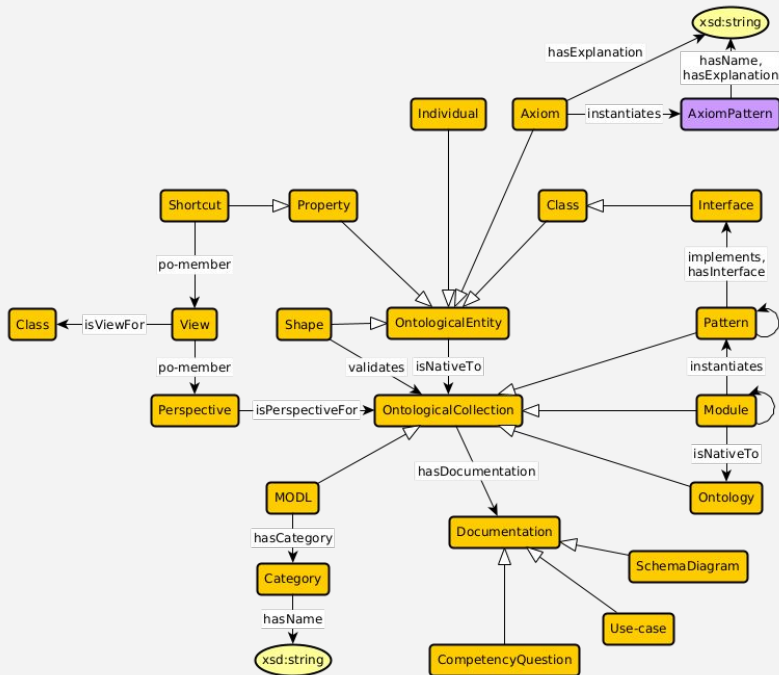
We use OPLa to formalize this scaffolding.

# OPaL: ODP representation Language

The language formerly known as “OPLa”

It is an annotation ontology which models how patterns are related to each other – as well as alternative specifications for the pattern (e.g., perspectives, shapes)

New specification forthcoming



# Modular Ontology Modeling

Modular Ontology can act as a bridge between human conceptualization and data.

- We have designed the modular ontology modeling methodology (right)
  - Focuses on empirical reality (i.e., which data actually exists)
  - Is a pattern based method
  - Limits exposure to formal logics

1. DEFINE THE USE CASE
2. MAKE COMPETENCY QUESTIONS
3. IDENTIFY KEY NOTIONS
4. MATCH PATTERNS TO KEY NOTIONS
5. INSTANTIATE THE PATTERNS
6. SYSTEMATIC AXIOMATIZATION
7. ASSEMBLE THE MODULES
8. REVIEW FINAL PRODUCT
9. PRODUCE THE OWL ARTIFACTS

# Outline & Objectives

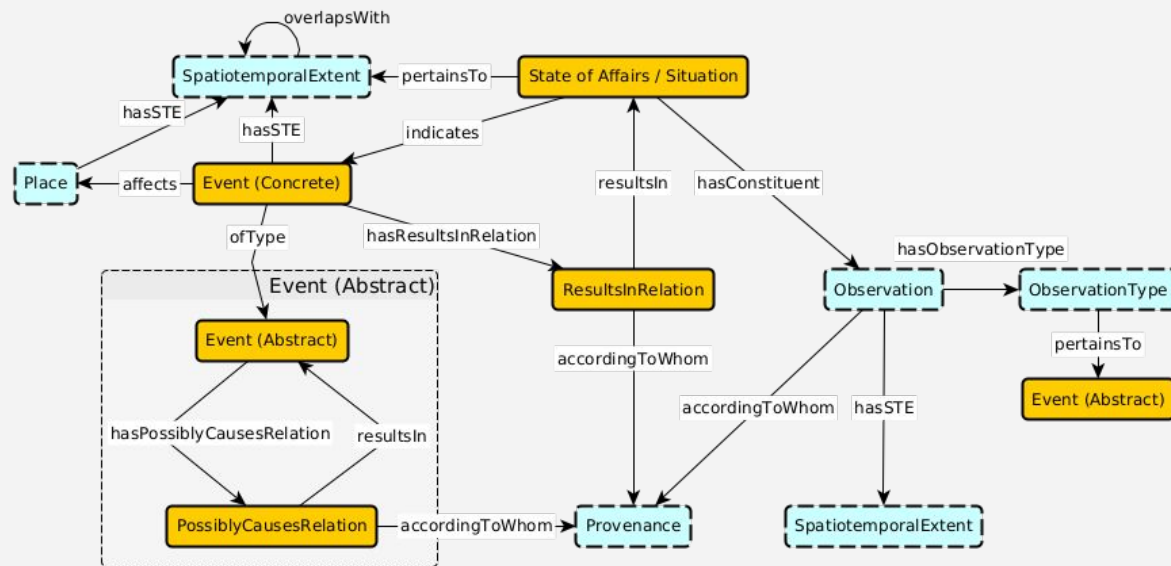
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Examples

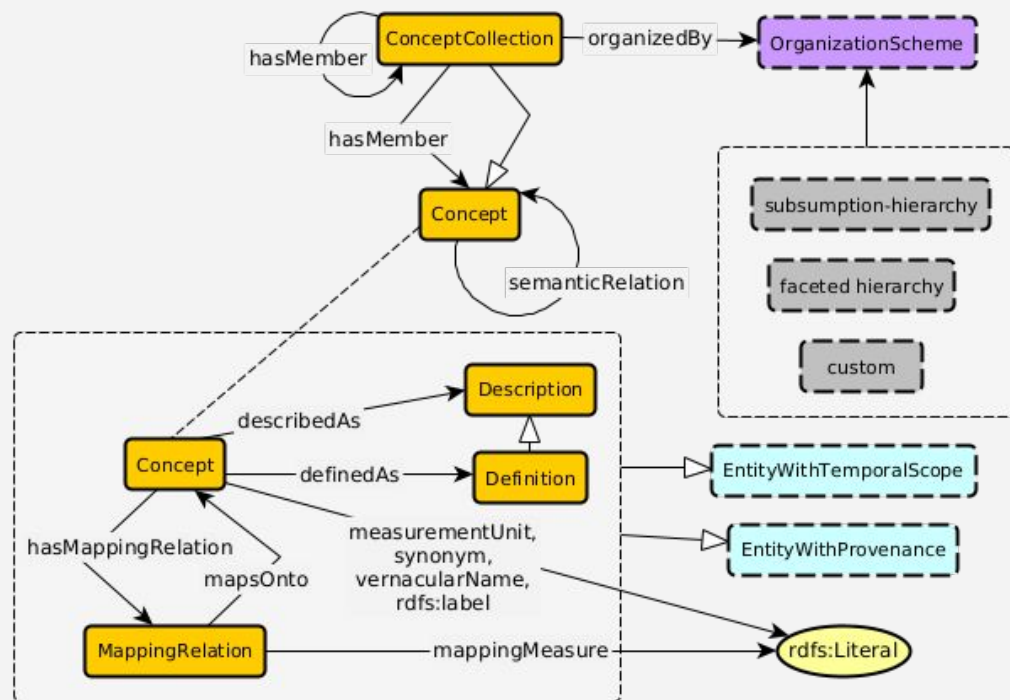
Tools & Resources

# An Example Pattern



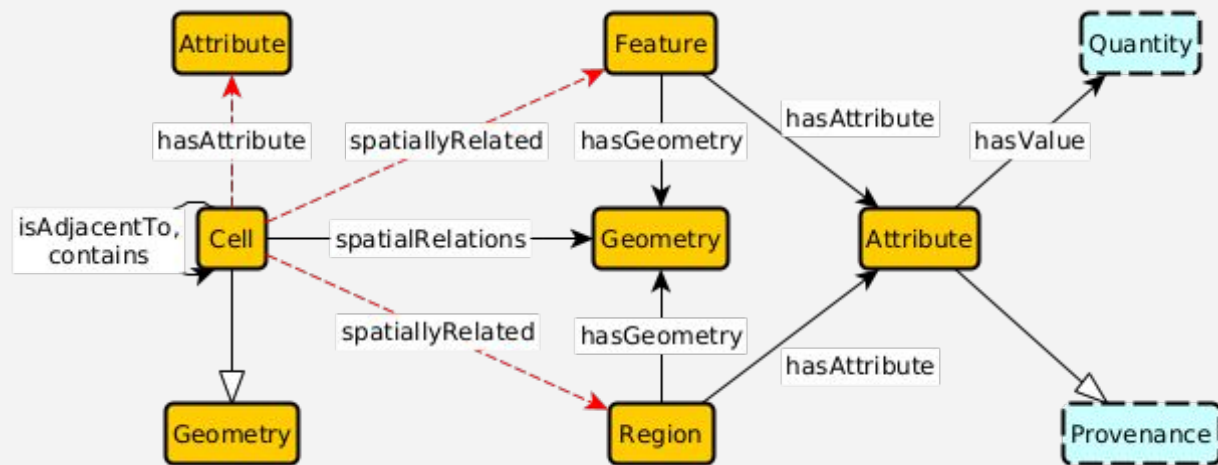
A Pattern for Depicting  
Causal Relationships  
between Events

# An Example Pattern



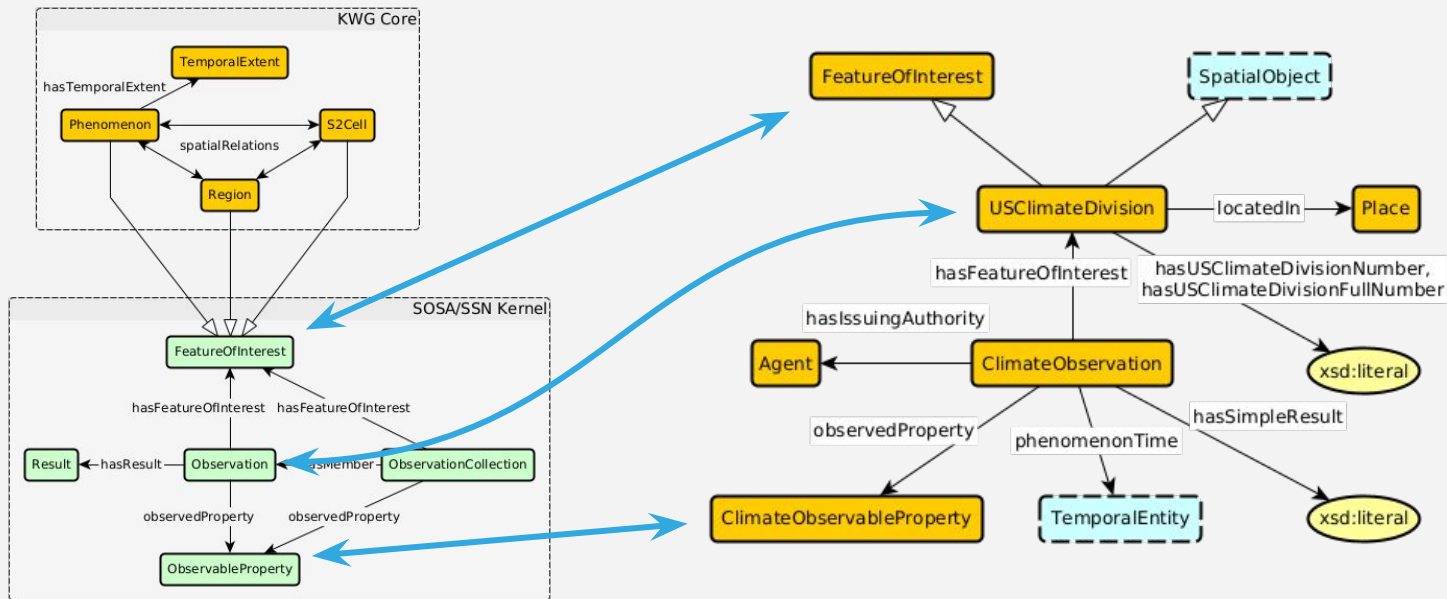
A Pattern for Aligning  
Vocabularies & Taxonomies

# An Example Pattern



A Pattern for Depicting  
Features of Cells in a  
Hierarchical Grid

# Template Based Instantiation



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# MODL: The Modular Ontology Design Library

- \* MODL is also an OPaL Ontology
- \* Contains 13 patterns in V1.  
Contains 32 patterns in V2 (forthcoming).
- \* Not just an artifact, but also a template – make your own MODL!
- \* Encodes many inter-pattern relationships  
– interfaces,  
specializations/generalizations, and  
categories

| Category                  | Patterns                                                                          |
|---------------------------|-----------------------------------------------------------------------------------|
| Metapatterns              | Explicit Typing<br>Property Reification<br>Stubs                                  |
| Organization of Data      | Aggregation, Bag, Collection<br>Sequence, List<br>Tree                            |
| Space, Time, and Movement | Spatiotemporal Extent<br>Spatial Extent<br>Temporal Extent<br>Trajectory<br>Event |
| Agents and Roles          | AgentRole<br>ParticipantRole<br>Name Stub                                         |
| Description and Details   | Quantities and Units<br>Partonymy/Meronymy<br>Provenance<br>Identifier            |

# The Ontology Design Patterns Portal

<https://ontologydesignpatterns.org/>



<https://github.com/odpa/patterns-respository>



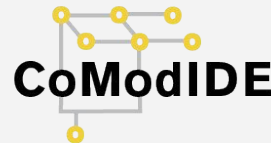
# The Comprehensive Modular Ontology IDE

The screenshot displays the CoModIDE interface with several key components:

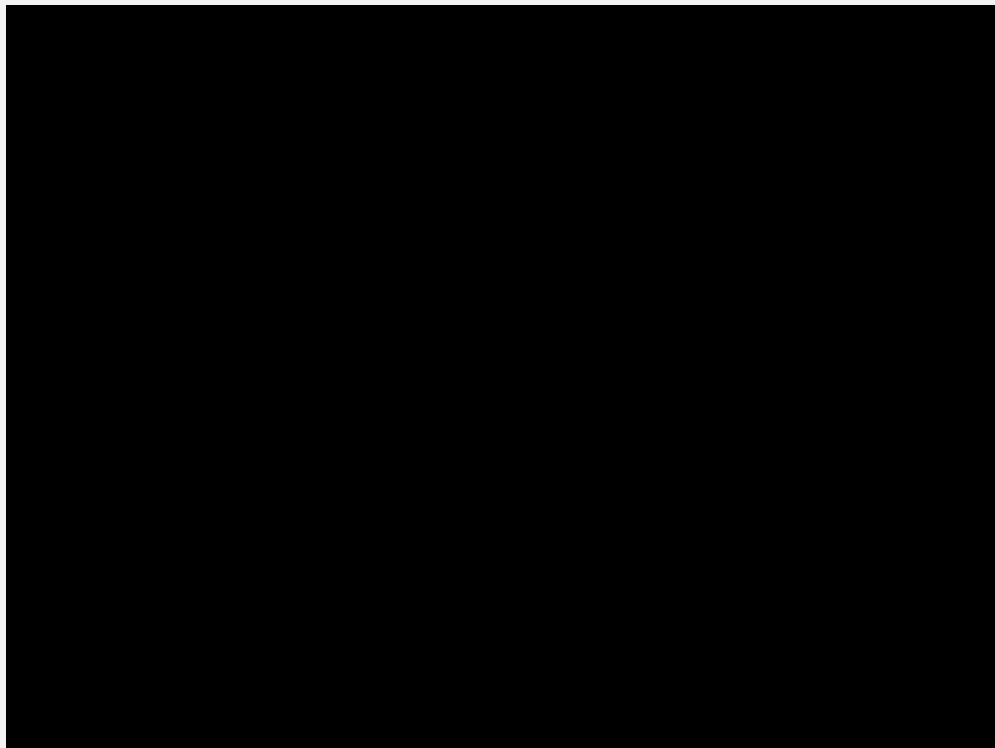
- CoModIDE Renderer:** A central workspace showing a hierarchical ontology diagram. A red circle with the number '1' highlights this area.
- CoModIDE Pattern Selector:** A panel on the right containing a 'Pattern Library' with a search bar and a list of patterns. A red circle with the number '2' highlights this panel.
- CoModIDE Configuration:** A panel on the right with settings for 'Entity naming' (radio buttons for 'Use target namespace' and 'Keep pattern namespace'), 'Module annotations placement' (radio buttons for 'External' and 'Internal'), and 'Edge creation' (checkboxes for 'RDFS Range', 'RDFS Domain', 'AllValuesFrom constraint', and 'SomeValuesFrom constraint'). A red circle with the number '3' highlights this panel.
- Core constructs:** A panel on the left with icons for 'Class', 'Property', and 'Subclass'.
- Active ontology:** A panel at the top left showing the current ontology's state.
- Entities by class:** A panel at the top left showing the entities belonging to the selected class.
- DL Query:** A panel at the top left for entering queries.
- CoModIDE:** The main application window title.

The bottom of the interface shows a status bar with the text 'To use the reasoner click Reasoner > Start reasoner' and a checkbox for 'Show Inferences'.

1. A Graphical Paradigm
2. A Pattern Library
3. Customizable Semantics



# The Comprehensive Modular Ontology IDE



THANKS!

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