OWL or SHACL?

A Beginner's Guide to Making the Right Choice

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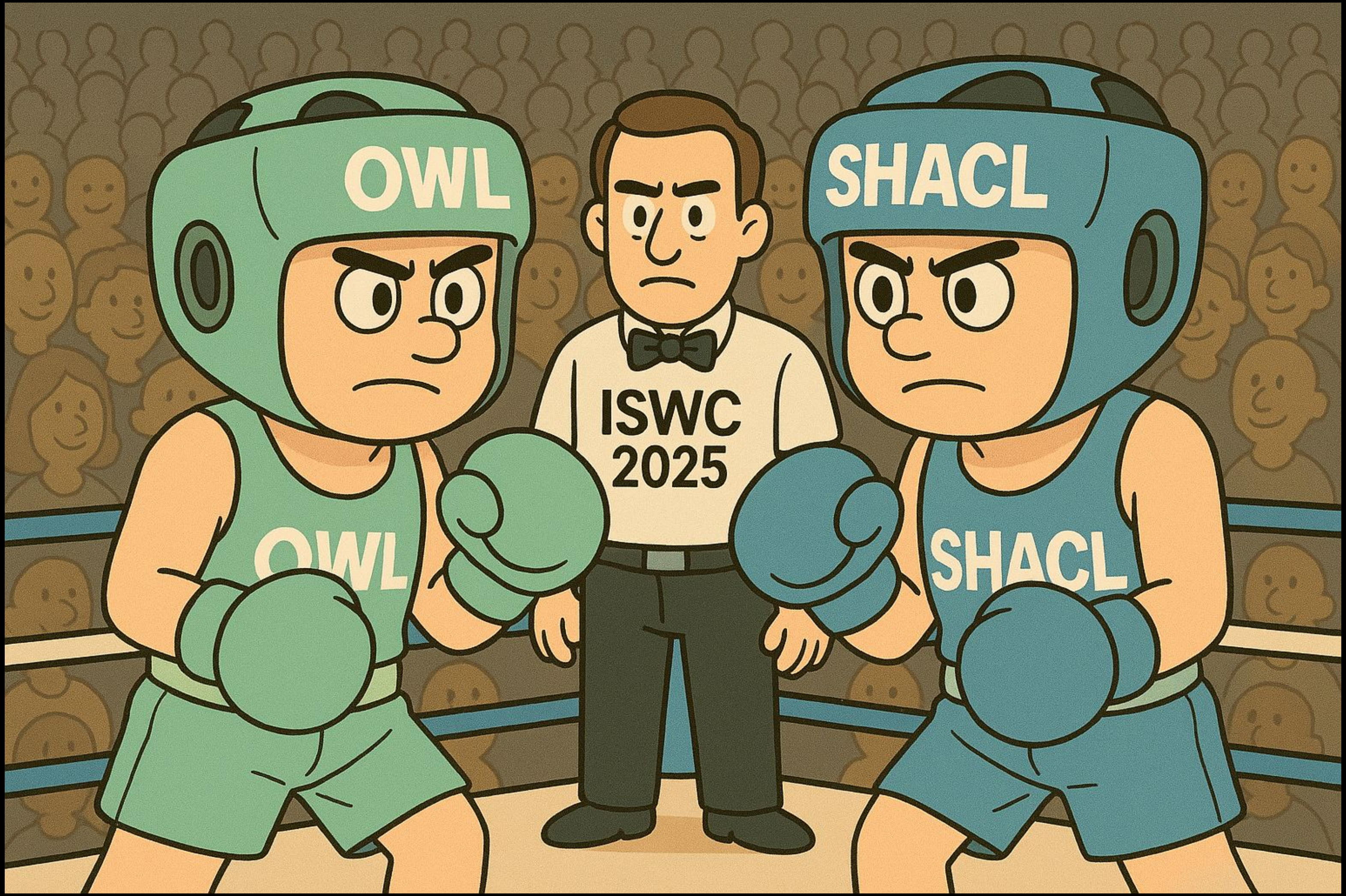
Bloomberg

The Ultimate Showdown: Game 1



Disclaimer: Created by ChatGPT

What are we learning today?

- This will be an “Example-Based” hands-on tutorial
  - Together, we will make a choice of OWL or SHACL (or both) to solve problems and understand the implications of the choice
- Main Focus: Comparing the strengths and weaknesses of OWL and SHACL
- We will talk about
  - Open World Closed world
  - Reasoning
  - Transitivity and Property chains
  - And more…..
- This will NOT be an in-depth tutorial of everything OWL or everything SHACL… if only we had more time :)

Some Logistics

- Download Protégé Desktop (NOT WebProtégé): https://protege.stanford.edu/
- Open SHACL playground: https://shacl-playground.zazuko.com/
- Open workshop page for all examples and code: https://tinyurl.com/owlshacl

When you see these icons

protégé

Go to Protégé

- For modeling in owl
- Adding data instances
- Using a reasoner
- Running SPARQL

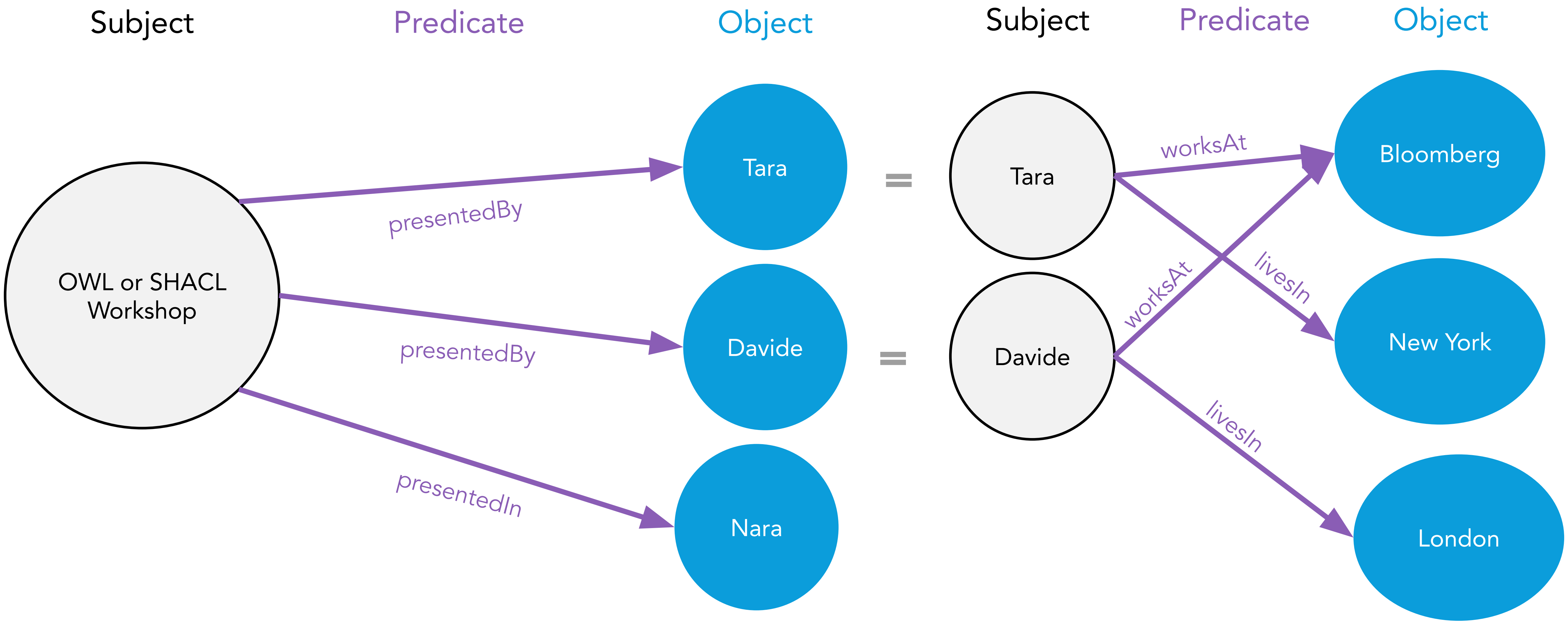
Go to SHACL playground

- For writing SHACL shapes
- For validating data graphs against SHACL shapes

Follow the instructions

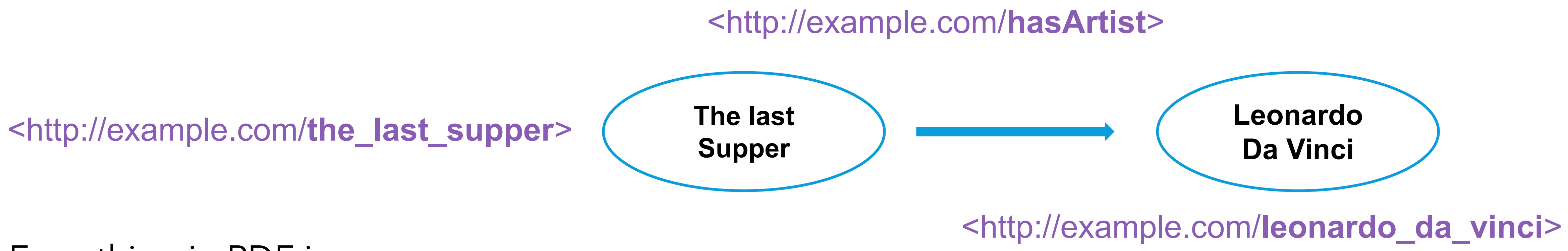
A Little Background

The World In Triples



RDF (Resource Description Framework)

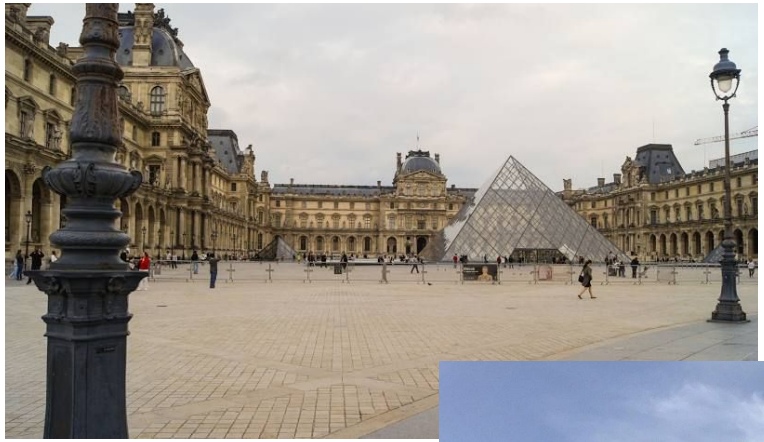
- W3C de facto standard for data interchange that is used for representing highly interconnected data
- Simple triple-based model: <subject> <predicate> <object>


<http://example.com/hasArtist>
<http://example.com/the_last_supper>
The last Supper
Leonardo Da Vinci
<http://example.com/leonardo_da_vinci>

- Everything in RDF is a resource
- Every resource has a unique identifier (URI or IRI)
- No schema

Things, not strings!

A day at the museum …



Walking through an exhibition …. A million questions !

- What artefacts do you have?
- All the information about them in terms of artist, date of creation, materials, etc.?
- When you create the exhibitions how do you decide what artefacts go together?
- Can you know which city or county an artefact is being exhibited?
- Based on the art movement era of the piece can you tell the artists of those eras?
- Is it possible for you to know whether a copy of an original art pieces you have exists somewhere else?
- Which piece was influenced by whom?

How do they organize their data?

- Related artefacts
- Artefact
- Owner
- Exhibited In
- Movements
- Exhibition
- Artist
- Culture
- Material
- Collection
- Creation Date
- Location
- Provenance
- Visitor
- Period/Era
- Influence
- Concept
- Technique
- Documentation

Tara

ROUND 1: Simple queries

Let’s create the onotlogy !

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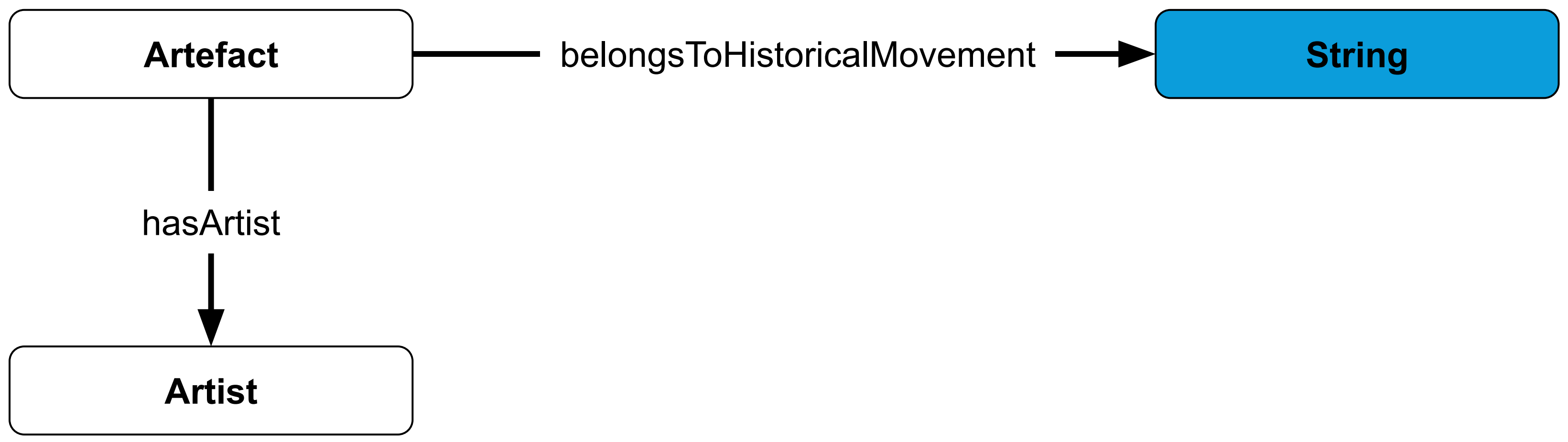
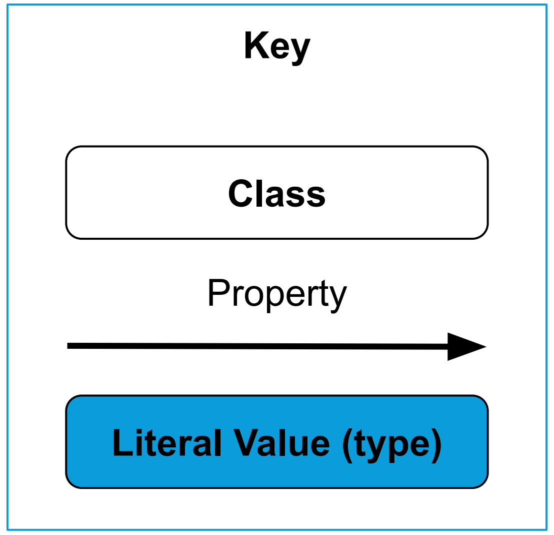
How do you decide on the design of the ontology model?

Start with the competency questions…

- What artefacts are attributed to a specific artist?
- What artefacts are associated with a specific historical movement?
- What artefacts are attributed to a specific artist and associated with a specific historical movement?

The Simple Ontology - Let's code that in OWL



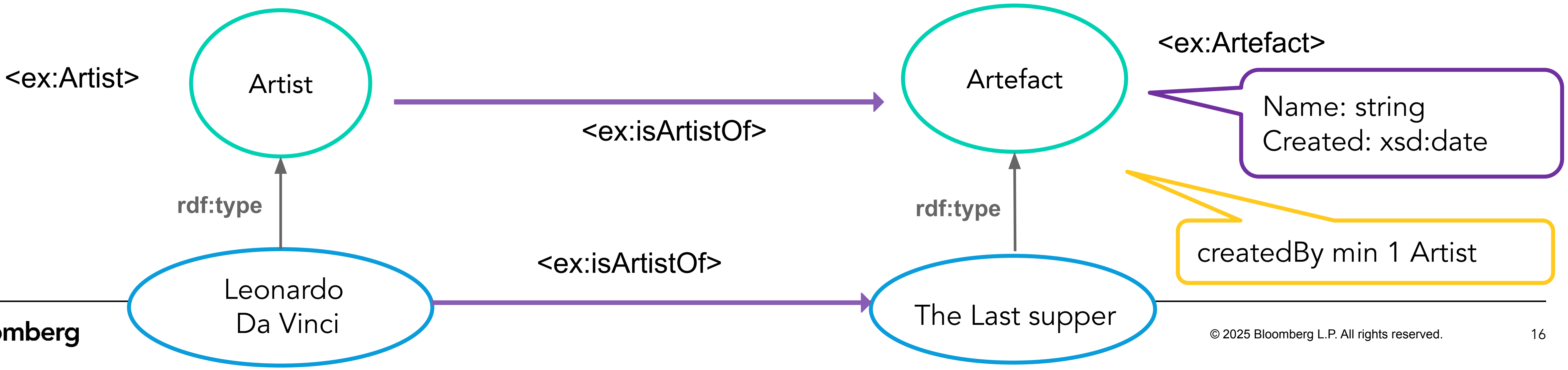


- Open model_00.ttl
- Add the above classes and properties

  Or
- Open model_01.ttl

OWL (Web Ontology Language)

- An RDF-based de facto standard for ontology development
- Main components include
  - Classes: define concepts in a domain
  - Properties:
    - Object properties: define relationships between concepts
    - Datatype properties: define relationships between a concept and a literal
  - Individuals: instances of classes
  - Restrictions: allow definition of cardinality restrictions, as well as existential & universal quantifications (some rules can be defined in the context of a restriction)



Let’s add the data

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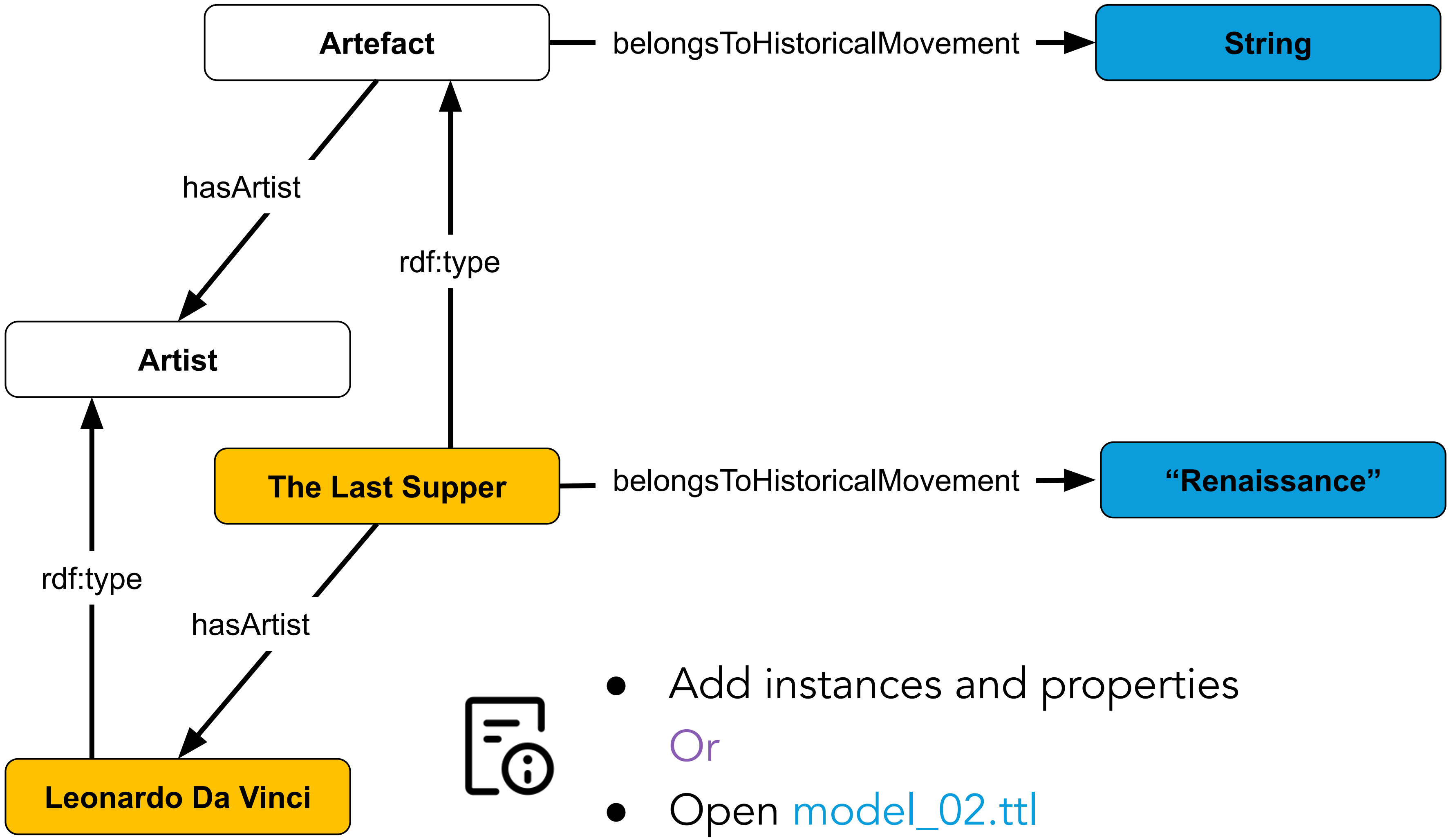
The Knowledge Graph



- Add instances and properties

  Or
- Open model_02.ttl

Fun Fact:
In 2007, an Italian musician claimed to have found musical notes in *The Last Supper* that result in a tuneful 40-second musical composition. The notes, which are 'hidden' in the bread rolls and hands of the apostles in the painting, is read from right to left, following Da Vinci's own writing style.

Source:https://www.livescience.com/2039-da-vinci-musical-code-supper.html

What is a knowledge Graph ?

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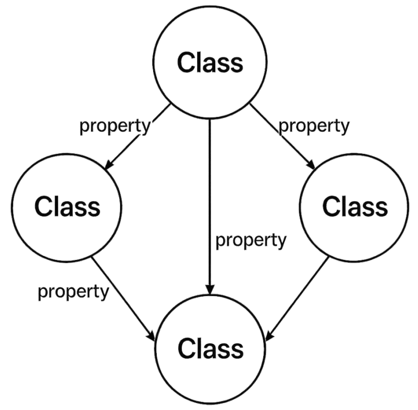
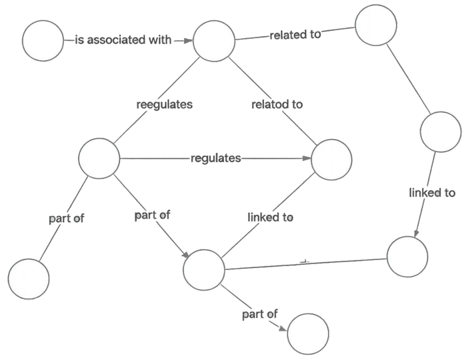
The Two Layers of the Knowledge Graph



Semantic Layer

Defines what things mean and how they relate to each other in a machine-understandable format



Data Layer

Real-world facts and observations mapped onto the semantic structure/layer

What is a Knowledge Graph?

*"A knowledge graph is the DNA of information —
It encodes not just facts, but the structure, relationships,
and rules that bring raw data to life and allow it to grow,
adapt, and evolve* *Tara Raafat*

Let's test the queries

1. What artefacts are attributed to Leonardo da Vinci?

```
SELECT ?x
WHERE {
   ?x a ex:Artefact ;
     ex:hasArtist ex:leonardo_da_vinci .
}
```

2. What artefacts are associated with the Renaissance movement?

```
SELECT ?x
WHERE {
   ?x a ex:Artefact ;
     ex:belongsToHistoricalMovement "Renaissance"^^xsd:string .
}
```

3. What artefacts are attributed to Leonardo da Vinci and associated with the Renaissance movement?

```
SELECT ?x
WHERE {
   ?x a ex:Artefact ;
     ex:hasArtist ex:leonardo_da_vinci ;
     ex:belongsToHistoricalMovement "Renaissance"^^xsd:string .
}
```

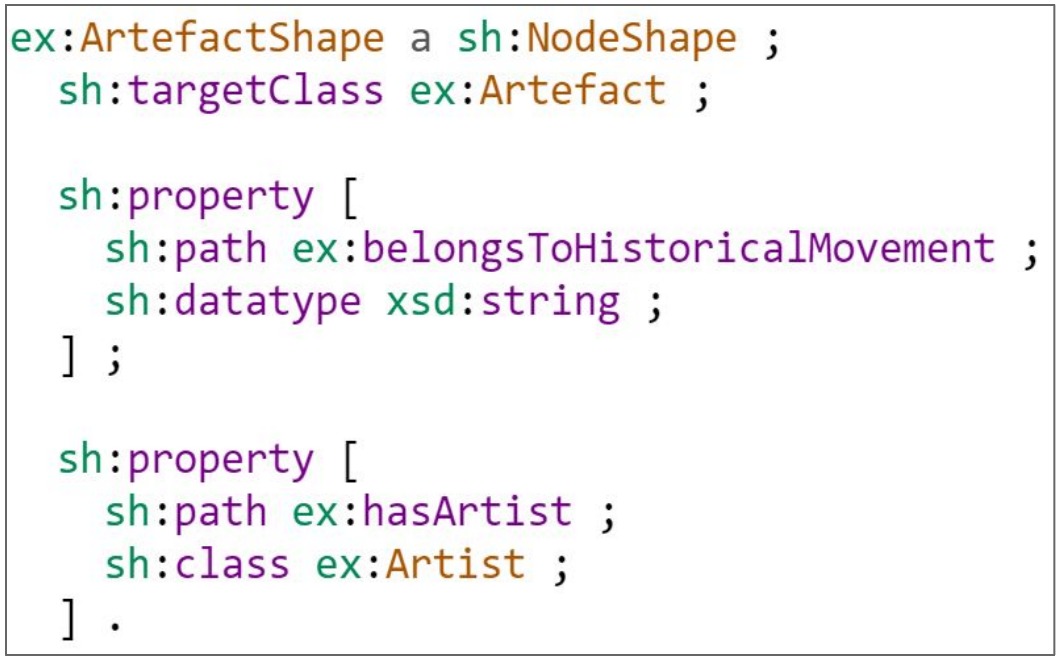
- Open model_02.ttl
- Open 'SPARQL" tab in the website
- Run the queries in Section 1

Can we answer those questions using SHACL?

Could SHACL be used to achieve this?

Yes!

Shape 1 in SHACL tab of website



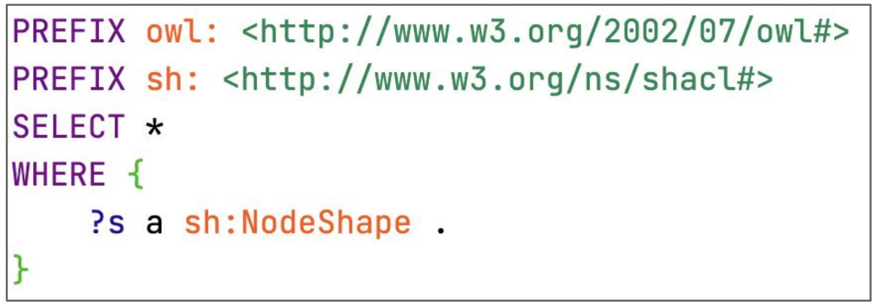
```
ex:ArtefactShape a sh:NodeShape ;
  sh:targetClass ex:Artefact ;

  sh:property [
    sh:path ex:belongsToHistoricalMovement ;
    sh:datatype xsd:string ;
  ] ;

  sh:property [
    sh:path ex:hasArtist ;
    sh:class ex:Artist ;
  ] .
```

Since you are querying the data , same SPARQL will provide the same answer

If you want to query the model then you have to write different SPARQL queries one on owl construct and one on shacl constructs



```
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX sh: <http://www.w3.org/ns/shacl#>
SELECT *
WHERE {
    ?s a sh:NodeShape .
}
```

However, if you want to use the same SPARQL query written in OWL syntax for both, you'll need tools that translate SHACL to OWL

But what if you want to do more?

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ROUND 2: Dealing with Incomplete Information

Let’s add more Data

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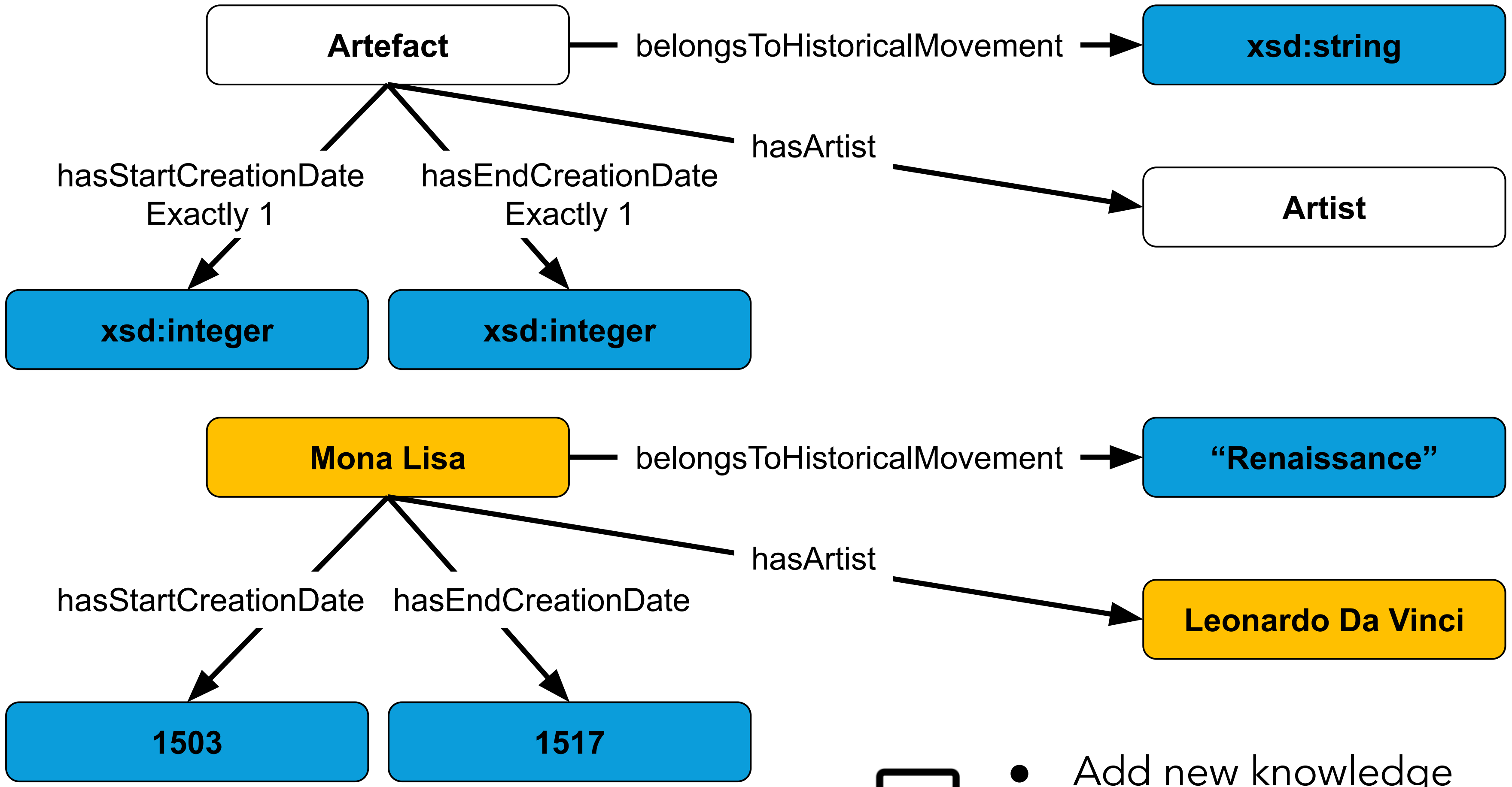
The Knowledge Graph extended



Fun Fact:
Leonardo da Vinci's *Mona Lisa* took 14 years for him to complete, starting in 1503 and continuing until nearly his death in 1517; reportedly, he continuously refined the painting throughout this period.

Source: Wikipedia

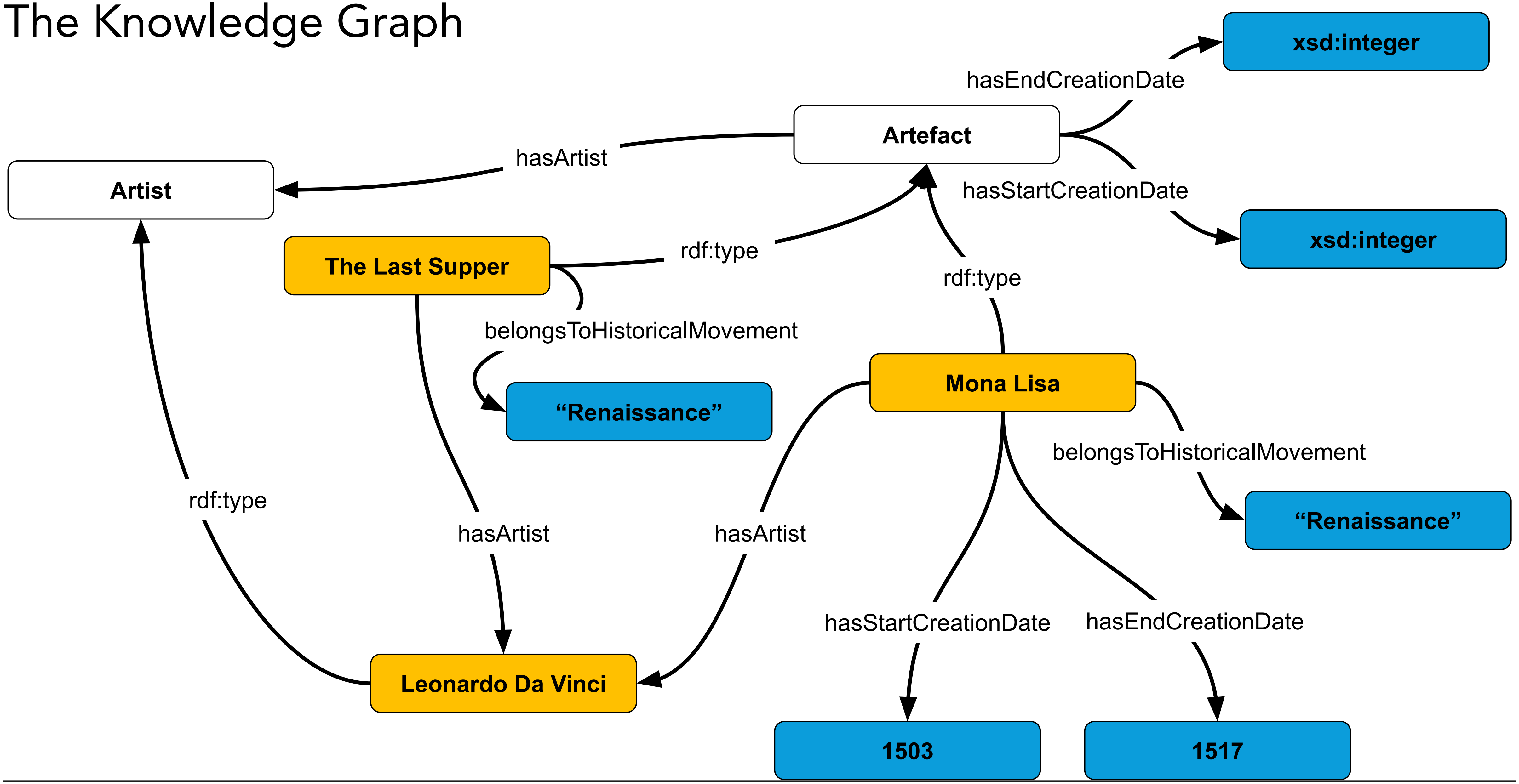
- Add new knowledge
  Or
- Open model_03.ttl

What about Missing (Incomplete) information?

Some artworks are acquired without complete information at the time of acquisition.

- How do museum systems typically handle missing data?
- Does the absence of certain metadata trigger an error?
- Should incomplete records be treated as errors?

The Knowledge Graph



Would OWL restrictions enforce data's existence & cause an error?

Artefact := hasStartCreationdate exactly 1 xsd:integer

Artefact := hasEndCreationdate exactly 1 xsd:integer

- Load model_03.ttl
- Run reasoner

The reasoner doesn't throw an error.

RESULTS

Why? Because OWL operates on an Open World Assumption (OWA) and assumes that the absence of information does not imply its absence in reality.

Open World Assumption (OWA)

If certain information does not exist in the data, it cannot be assumed to be false, it's simply incomplete.

In such cases, an OWL reasoner does not return an error; it simply does not infer anything additional from the missing information.

When is the OWA useful?

The OWA is particularly valuable in scenarios where not all knowledge is known or available at a given time. In such contexts, the use of an ontology under OWA supports ongoing discovery by remaining flexible, adaptable, and collaborative.

New information can be added over time without invalidating existing assertions, enabling systems to grow and evolve without requiring full knowledge upfront.

What if you wanted to ensure the data existed at the time of acquisition?

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Davide

ROUND 3: Validation

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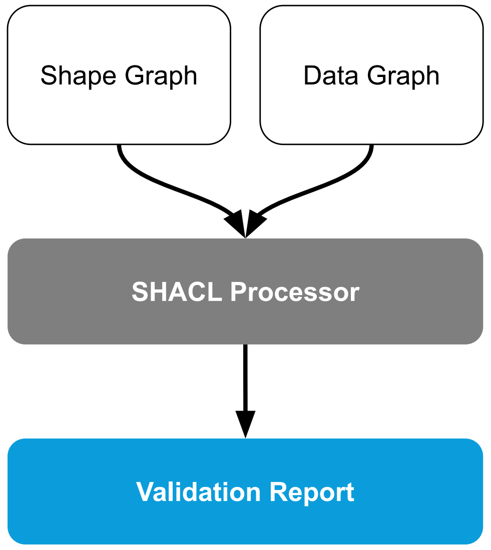
Let’s test SHACL

We need to define the exact shape of our data, including the required properties and any constraints on their values.

SHACL shapes are required to validate RDF data against specific structural and value constraints.



Shape 2

```
ex:ArtefactShape a sh:NodeShape ;
  sh:targetClass ex:Artefact ;

  sh:property [
    sh:path ex:belongsToHistoricalMovement ;
    sh:datatype xsd:string ;
  ] ;

  sh:property [
    sh:path ex:hasArtist ;
    sh:class ex:Artist ;
  ] ;

  sh:property [
    sh:path ex:hasEndCreationDate ;
    sh:datatype xsd:integer ;
    sh:minCount 1 ;
    sh:maxCount 1 ;
  ] ;

  sh:property [
    sh:path ex:hasStartCreationDate ;
    sh:datatype xsd:integer ;
    sh:minCount 1 ;
    sh:maxCount 1 ;
  ] .
```

Validity Conditions

```
sh:property [
   sh:path ex:hasEndCreationDate ;
   sh:datatype xsd:integer ;
   sh:minCount 1 ;
   sh:maxCount 1 ;
] ;

sh:property [
   sh:path ex:hasStartCreationDate ;
   sh:datatype xsd:integer ;
   sh:minCount 1 ;
   sh:maxCount 1 ;
] .
```

The validation shows error.

Why? Because SHACL operates on an Closed World Assumption (CWA) and assumes that the absence of information is an error in reality.

Closed World Assumption (CWA)

- The system assumes it has all the information it needs about its domain.
- Anything not explicitly known or stated as true is assumed to be false => Missing information is assumed to be false, the data graph is flagged as invalid.
- If a data node does not meet the defined restrictions, such as a wrong value type for a property, it results in a validation error.

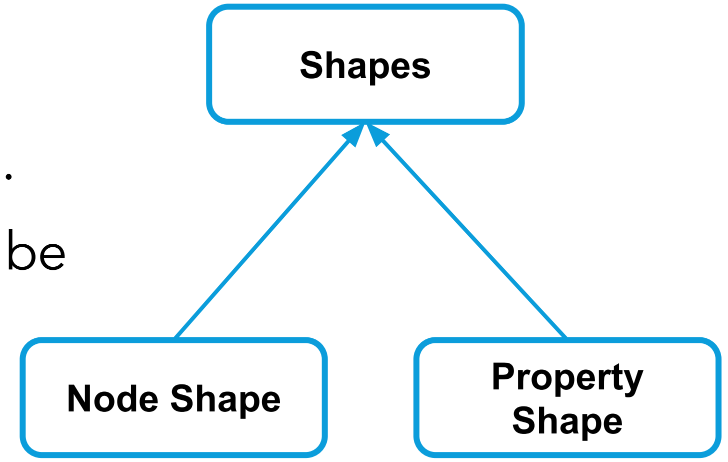
When is the CWA useful?

The CWA is particularly valuable in scenarios where data integrity is crucial and error reports need to be generated if information is missing or invalid

The SHACL Shape

In SHACL, a shape is composed of targets and constraints.

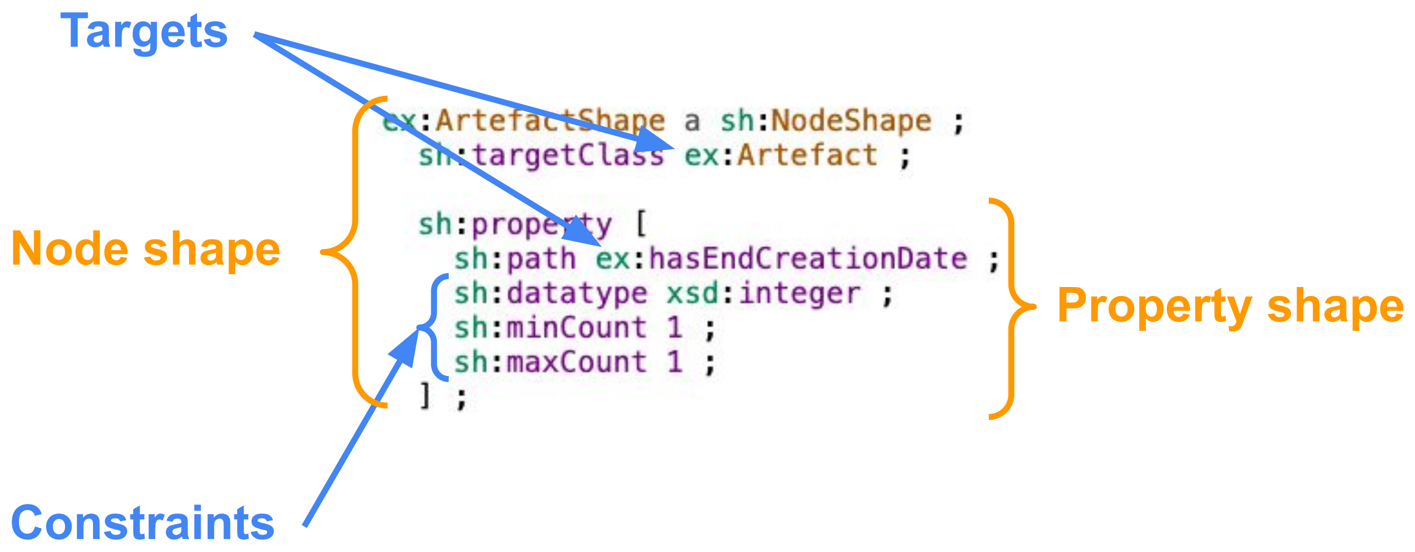
- Targets identify the nodes in the data graph that the shape applies to.
- Constraints specify the rules that those nodes must satisfy in order to be considered valid.



declare constraints directly on a node

declare constraints on the property that is connected to the node through a path

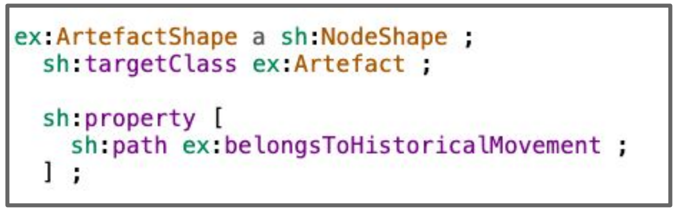
The sequence of edges through which a property is connected to a node



```
ex:ArtefactShape a sh:NodeShape ;
  sh:targetClass ex:Artefact ;

  sh:property [
    sh:path ex:hasEndCreationDate ;
    sh:datatype xsd:integer ;
    sh:minCount 1 ;
    sh:maxCount 1 ;
  ] ;
```

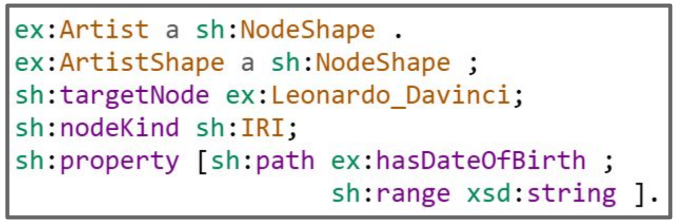
Targets

sh:targetClass



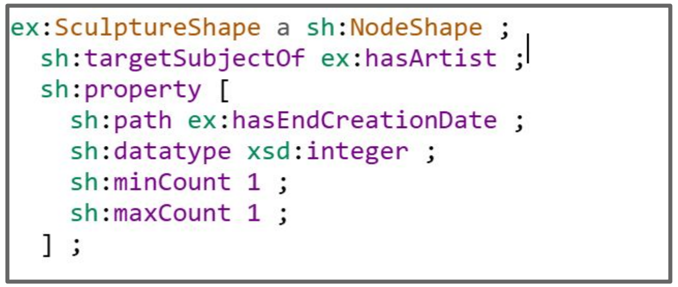
```
ex:ArtefactShape a sh:NodeShape ;
  sh:targetClass ex:Artefact ;

  sh:property [
    sh:path ex:belongsToHistoricalMovement ;
  ] ;
```

sh:targetNode



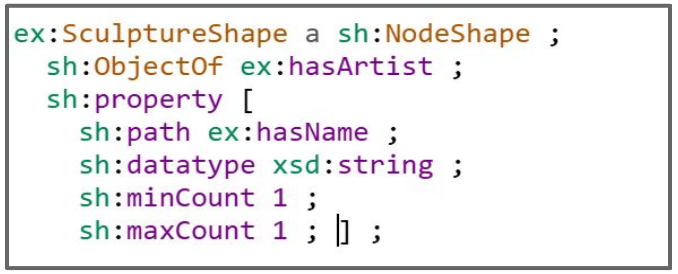
```
ex:Artist a sh:NodeShape .
ex:ArtistShape a sh:NodeShape ;
sh:targetNode ex:Leonardo_Davinci;
sh:nodeKind sh:IRI;
sh:property [sh:path ex:hasDateOfBirth ;
                   sh:range xsd:string ].
```

sh:targetSubjectOf



```
ex:SculptureShape a sh:NodeShape ;
  sh:targetSubjectOf ex:hasArtist ;
  sh:property [
    sh:path ex:hasEndCreationDate ;
    sh:datatype xsd:integer ;
    sh:minCount 1 ;
    sh:maxCount 1 ;
  ] ;
```

sh:targetObjectOf



```
ex:SculptureShape a sh:NodeShape ;
  sh:ObjectOf ex:hasArtist ;
  sh:property [
    sh:path ex:hasName ;
    sh:datatype xsd:string ;
    sh:minCount 1 ;
    sh:maxCount 1 ; ] ;
```

Recap so far…

Open world: missing information does not cause an error OWL

Closed world: missing information causes and error SHACL

Data Integrity: SHACL
Data Validation: SHACL

Tara

ROUND 4: Classification

What about Classification?

Museums regularly acquire new artefacts and classify them according to internal categorization systems.

Can this classification be automated? For instance, could a system infer whether an artefact is a painting or a sculpture based on metadata available at the time of acquisition?

- On model_03.ttl
- Add start and end creation dates for 'The Last Supper' (1494-1498)
- Add the data about David on the right

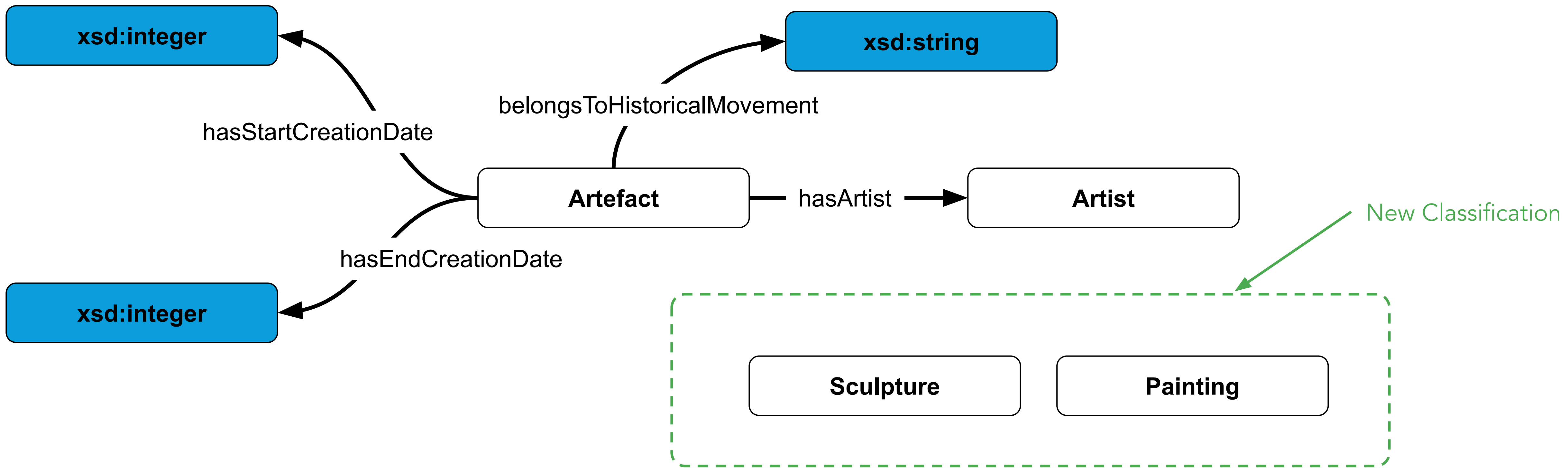
  Or
- Open model_04.ttl

```
ex:david
        ex:belongsToHistoricalMovement “Renaissance” ;
        ex:hasArtist ex:michelangelo ;
        ex:hasEndCreationDate 1504 ;
        ex:hasStartCreationDate 1501 ;
        ex:hasSculptureMaterial “Marble” ;
        rdfs:label "David" .
```

Let’s Extend Our Ontology

Bloomberg

Ontology extension



- Add two new classes Sculpture and Painting
  Or
- Open model_05.ttl
- Run the reasoner

Classification Query

Using the new model and the data we had about David sculpture;

Can we query the data to see what's sculptures we have?

Let's query the data for Sculpture (SPARQL query 2.1):

```
SELECT ?x

WHERE {
   ?x a ex:Sculpture .
}
```

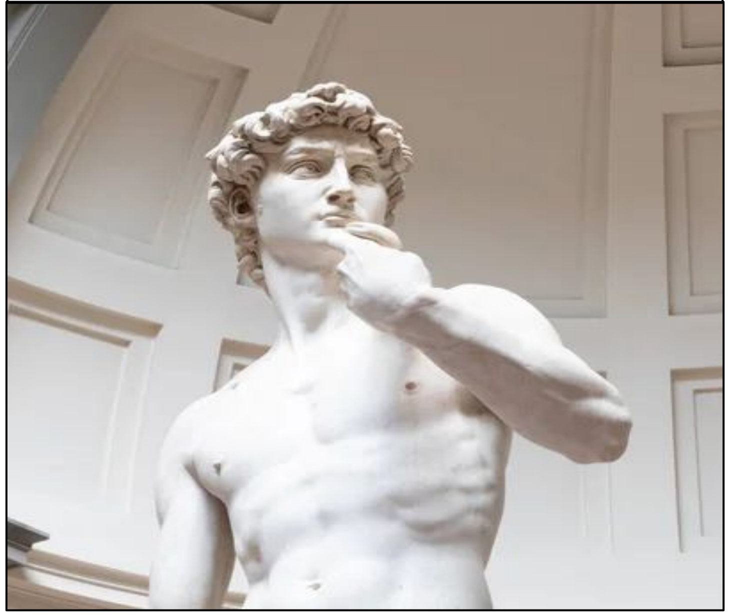
RESULTS

Nothing!
Why? There is neither a definition for the class sculpture nor a definition of the property hasSculptureMaterial.

Fun Facts:
The statue was carved from a single block of marble.

David's right hand is disproportionately large compared to his body because in the Middle Ages, David was said to be "manu fortis", meaning strong of hand.

There are at least 30 full-size replicas of this statue around the world.



Source: https://www.contexttravel.com/blog/articles/ten-facts-about-the-statue-of-david

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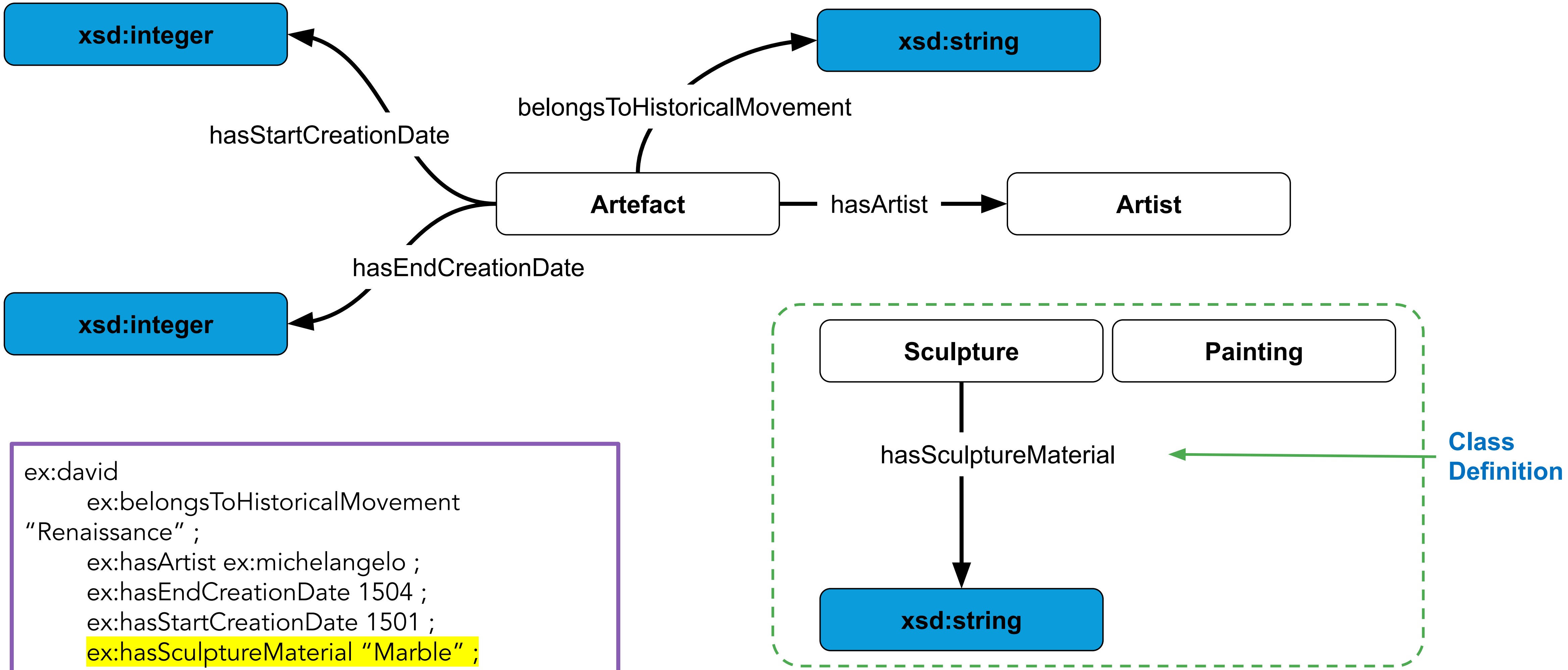
Class Definition



```
ex:david
        ex:belongsToHistoricalMovement
"Renaissance" ;
        ex:hasArtist ex:michelangelo ;
        ex:hasEndCreationDate 1504 ;
        ex:hasStartCreationDate 1501 ;
        ex:hasSculptureMaterial "Marble" ;
        rdfs:label "David" .
```

Classification by Class Definition

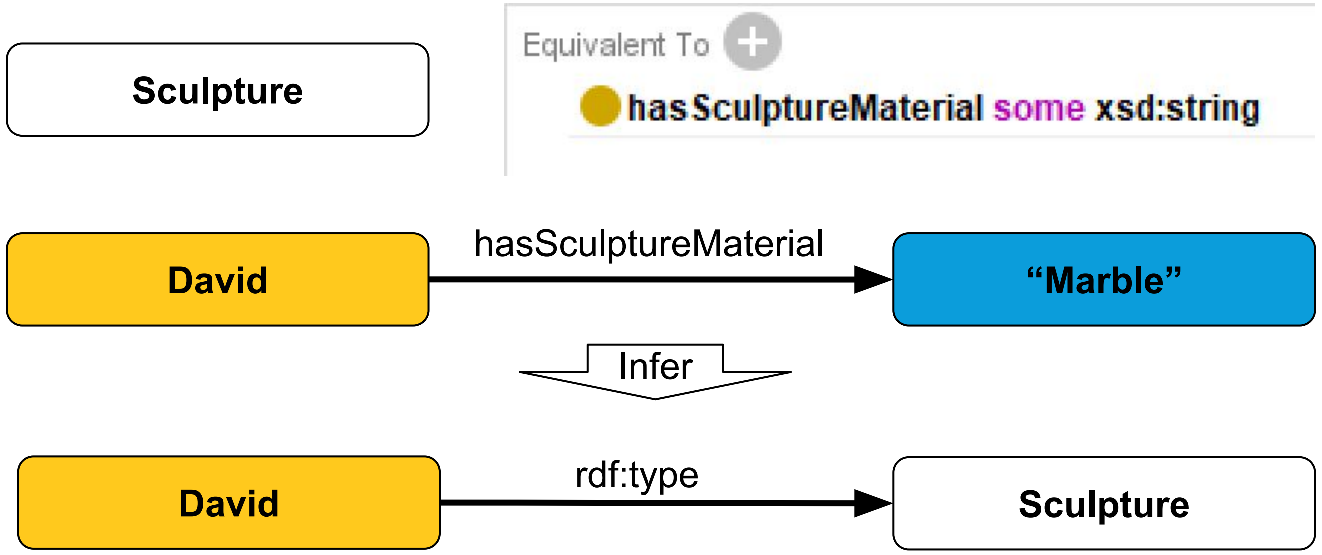
- Add the class definition
  Or
- load model_06.ttl
- Run the reasoner
- Add the changes suggested by the reasoner
  Or
- upload model_06_inferred.ttl
- Run the query 2.1 again

```
SELECT ?x

WHERE {
    ?x a ex:Sculpture .
}
```

Class Definition

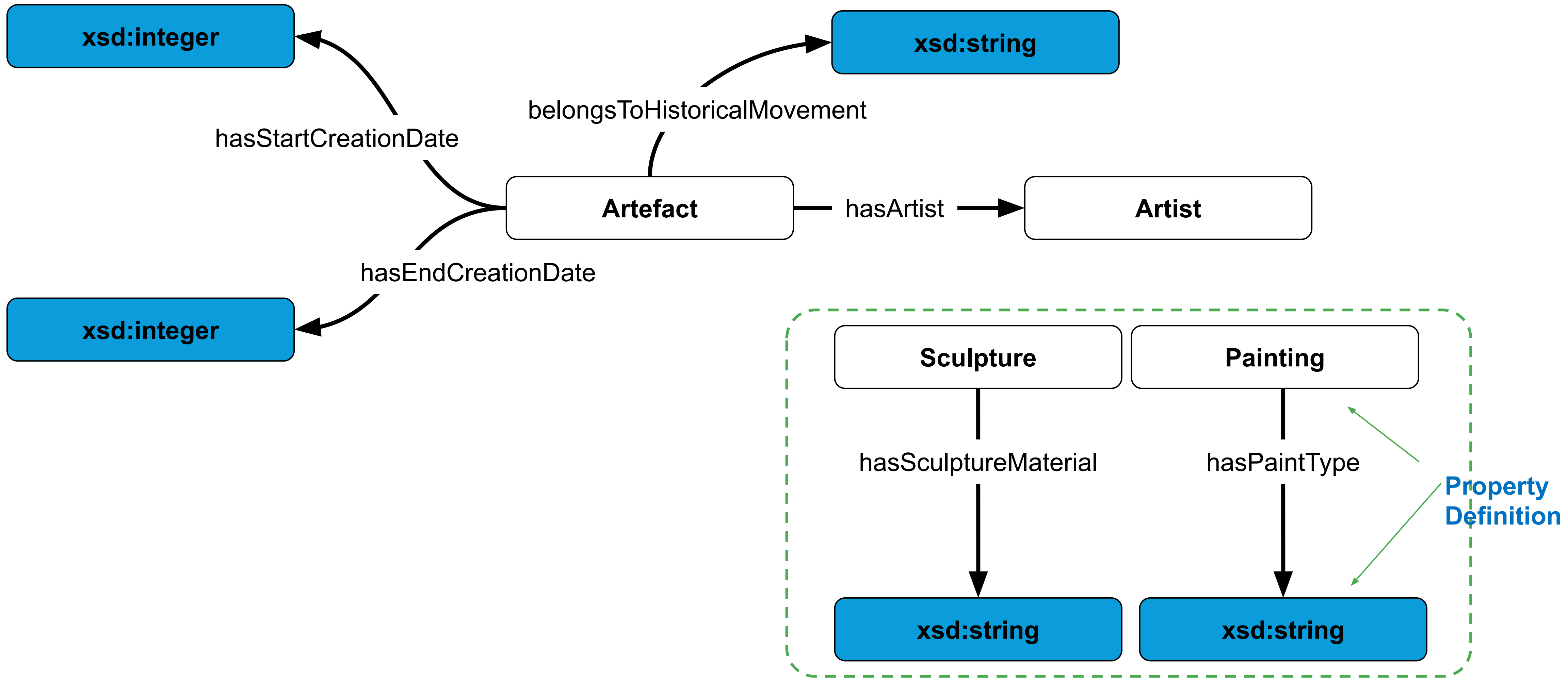
A sculpture has some sculpture material

RESULTS David
Why?



● hasSculptureMaterial some xsd:string

Property Definition



Classification by Property definition

Property definition:

ex:hasPaintType owl:domain Painting

ex:hasPaintType owl:range xsd:string

At the data level:

ex mona_lisa ex:hasPaintType "Oil paint"

ex:the_last_supper ex:hasPaintType "Mural Paint"

- Add the new knowledge
  Or
- load model_07.ttl
- Run the reasoner
- Add the changes suggested by the reasoner
  Or
- upload model_07_inferred.ttl
- Run query 2.2

Classification by Property definition

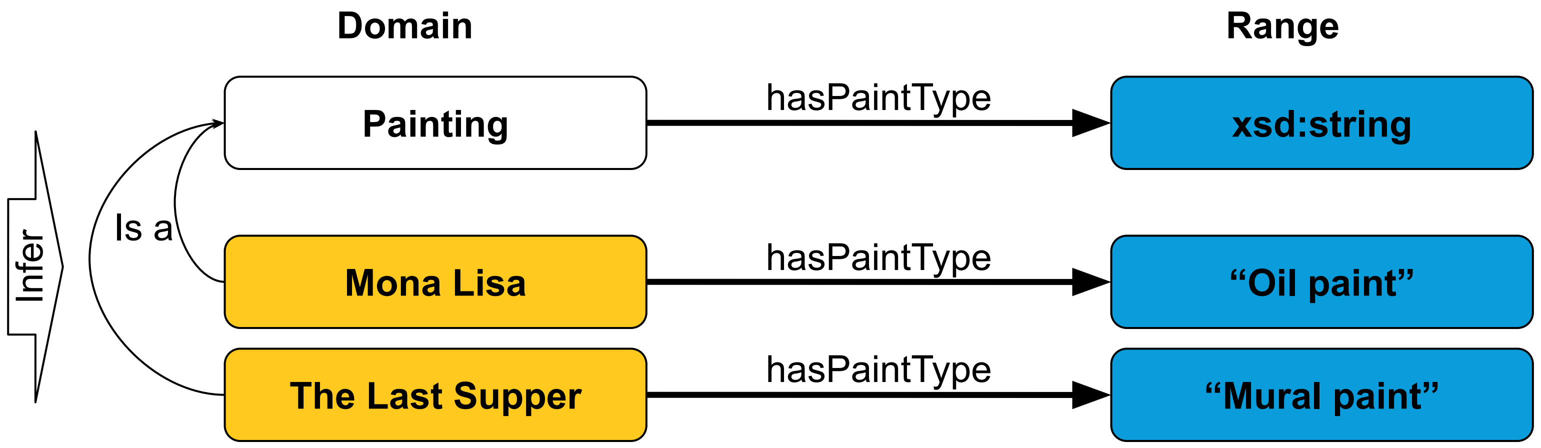
Query 2.2

```
SELECT ?x

WHERE {
   ?x a ex:Painting .
}
```

RESULTS

Mona Lisa & Last Supper

Why? Based on the "hasPaintType" definition



Classification Query

With all the data we have, can we query to see what are all the artefacts we have?

Query 2.3

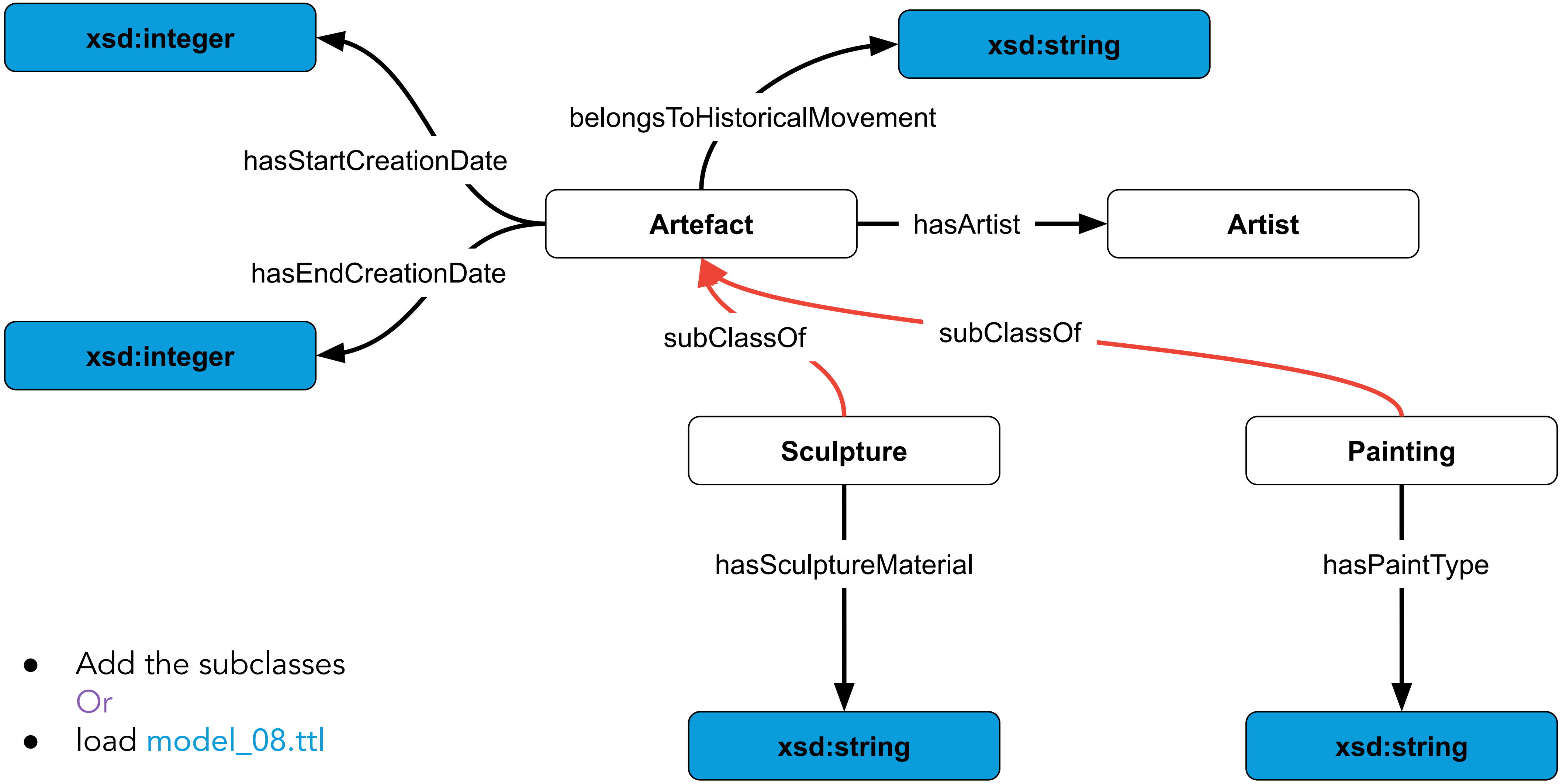
```
SELECT ?x

WHERE {
    ?x a ex:Artefact .
}
```

x
ex:mona_lisa
ex:the_last_supper

We did not get "David"!

Why? There's no subclass relationship defined between the sculpture class and the Artefact class.

Extend the Model



- Add the subclasses

  Or
- load model_08.ttl

The Subclass inference

- Run query 2.4

  Or
- load model_09.ttl
- Run query 2.5

x
ex:mona_lisa
ex:the_last_supper
ex:david

Query 2.4

```
SELECT DISTINCT ?x
WHERE {
    ?x rdf:type/rdfs:subClassOf*
ex:Artefact .
    }
```

Inference/reasoning logic in Query (inference on read)

Query 2.5

```
SELECT DISTINCT ?x
WHERE {
    ?x rdf:type ex:Artefact .
```

Inference/reasoning logic materialised in the knowledge graph (inference on write)

Inference for Classification

One of the main reasons to use OWL is its capability of making inferences

Inference can happen based on:

- Definition of the class through its properties and restrictions
- Specifying the domain and range of a property
- Through the subclass/superclass relationship

On its own, the W3C standard SHACL-Core does not support inference

NOTE: For inference, please see SHACL Advance Features (W3C draft document)

So, how do Restrictions in OWL & SHACL differ?

Bloomberg

OWL & SHACL Restrictions Compared

In OWL, the restriction purpose is Classification of resources based on the values they have:

- If something has these properties and restriction, then it is of this class type, as we saw in the Sculpture example- (in the implementation you have to define these restrictions as necessary and sufficient .
- OWL is property-oriented, meaning that the definition of a class is based on its properties and the restrictions on those properties

In SHACL, the restriction purpose is for Validation, and the logic is reverse meaning:

- If something is of a class/target type, then it has these properties
- And, if it doesn’t have those properties, it will fail the validation

Recap so far…

Open world: missing information does not cause an error OWL

Inference for Classification: OWL

- Class definition
- Property domain and range
- Subclass relationship

Closed world: missing information causes and error SHACL

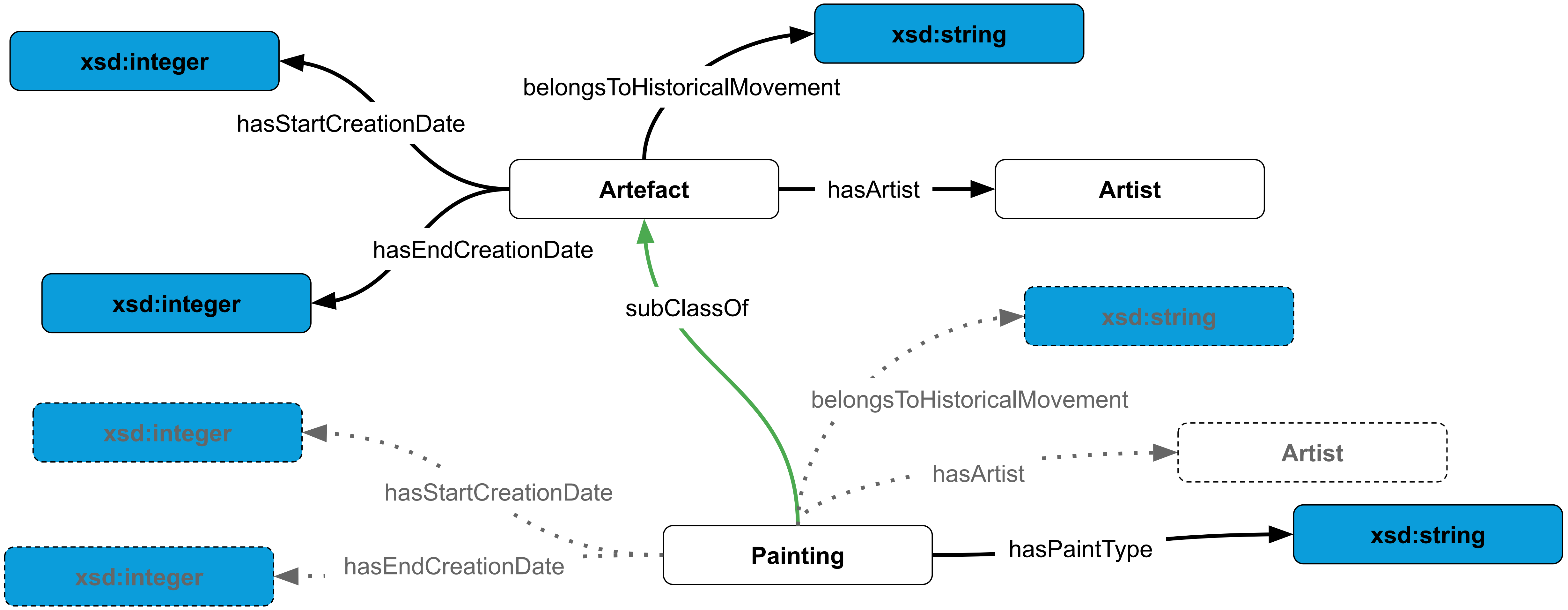
- Data Integrity: SHACL
- Data Validation: SHACL

Davide

ROUND 5: Inheritance

Inheritance in OWL

Subclass superclass inheritance is native to owl what it means :



Validation using inheritance in SHACL

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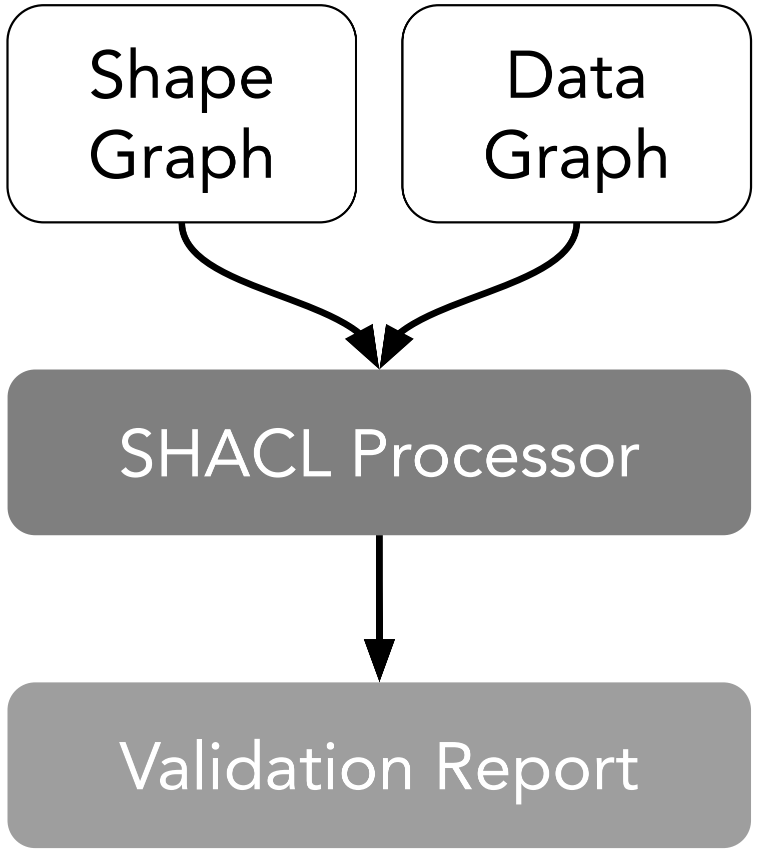
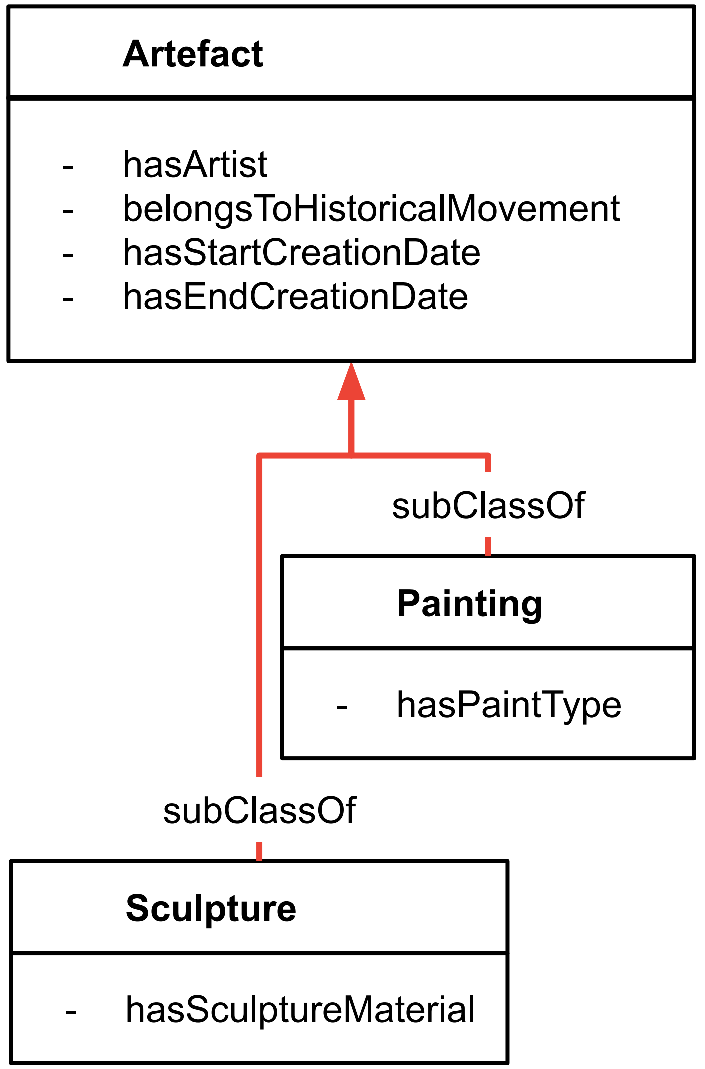
Validating with SHACL



Let’s test our shape with the data in SHACL Playground

subClass inheritance



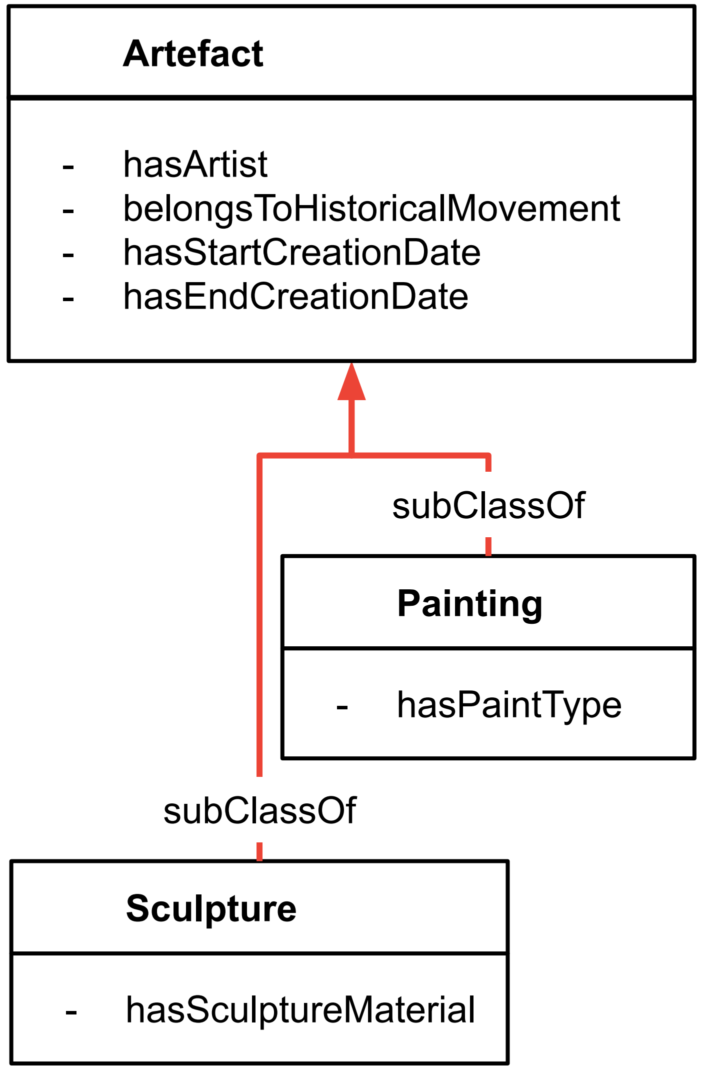
- Run Shape 3
- The data graph conforms to the shape, hence, no error
- If we change one of the date from integer to string

RESULTS Still no Error!

The expectation is to inherit all properties of the super class Artefact -> but that didn't happen!

WHY? Defining the subclass relationship in SHACL is different from the one in OWL, let's dive deeper into this

Making subClass inheritance work in SHACL



There are three ways to make it work:

1. Adding all the inference materialised in the data graph - Shape 4
2. Adding the semantic/knowledge level to the data graph - Shape 5
3. Adding `sh:node` on the SHACL side - Shape 6

If OWL subclassing says "*Every instance of A is also an instance of B*", the SHACL `sh:node` says "*Every A must have data that conforms to shape B*"

SHACL: Closed Shape

By default, SHACL shapes are open, which means:

- A node can have additional properties beyond those specified in the shape.
- SHACL only checks constraints on the properties you define; it ignores others.

However, SHACL also allows you to define closed shapes

- A node must only have the properties I explicitly permit here, any other properties are invalid.

```
ex:ArtefactShape a sh:NodeShape ;
  sh:targetClass ex:Artefact ;
  sh:closed true ;
  sh:ignoredProperties (rdf:type rdfs:label) ;
```

But when you close the shapes then…

- With semantic/knowledge level + `sh:node` | Shape 7
- With materialized data + `sh:node` | Shape 8
- With everything | Shape 9

What if we need different data restrictions for different applications?

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Tara

ROUND 6: Multiple Shapes of Data

One model, multiple shapes

Imagine another museum using the same ontology, but with an additional requirement: they need to ensure that the current owner or seller of an artefact is captured at the time of acquisition.

Does this mean they must create a completely new ontology? Not necessarily

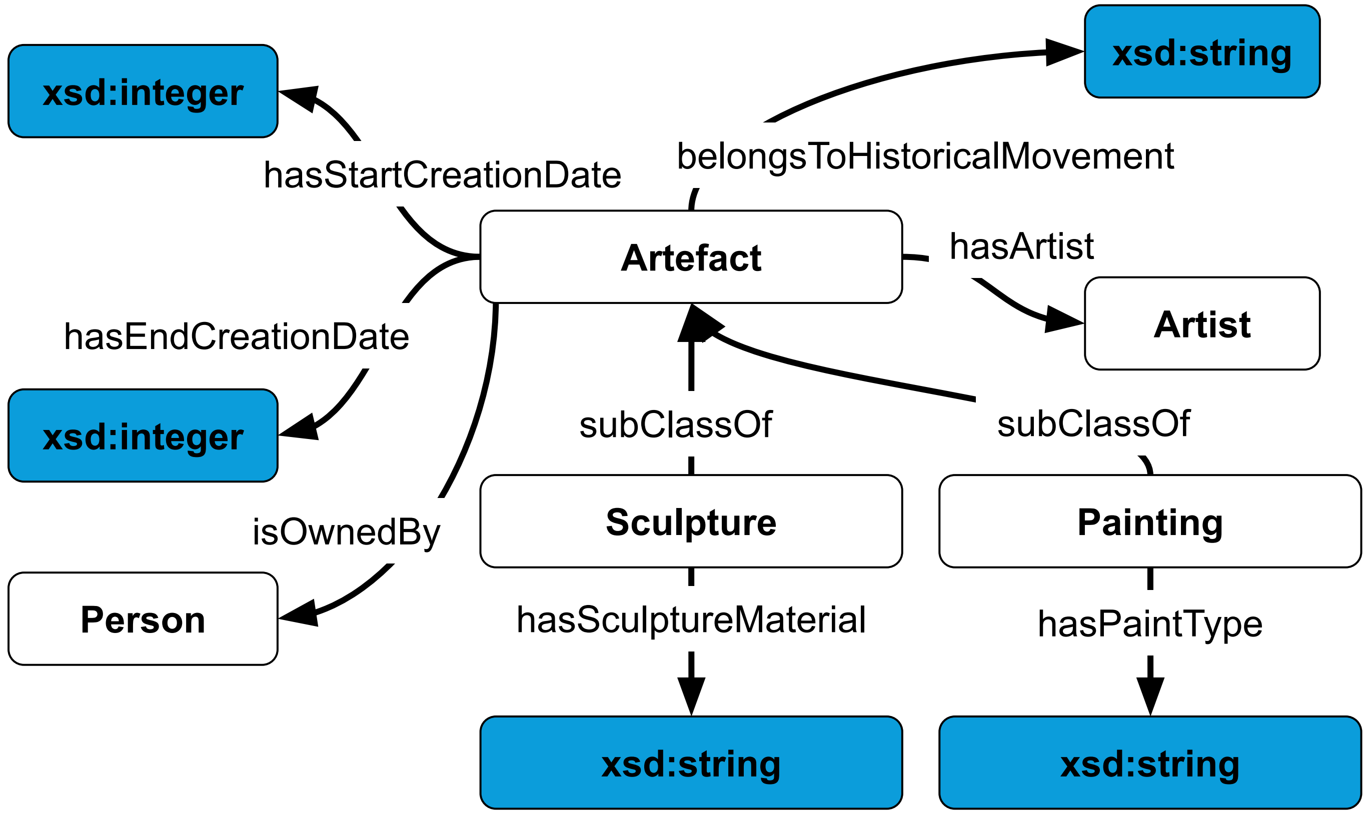
- Extend the current ontology: Add properties such as isOwnedBy and classes like Person.

```
ex:Artefact
        ex:isOwnedBy ex:Person .
```

- Define a new shape: Define a different SHACL shape that validates their specific data needs for their use case

```
sh:property [
  sh:path ex:isOwnedBy ;
  sh:class ex:Owner ;
  sh:minCount 1 ;
  sh:maxCount 1 ;
] ;
```

One model, multiple shapes



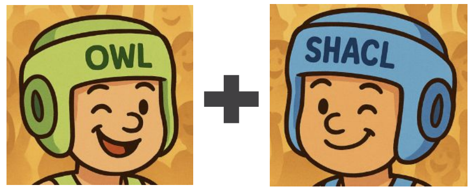
SHACL shape museum 1

Shape 10

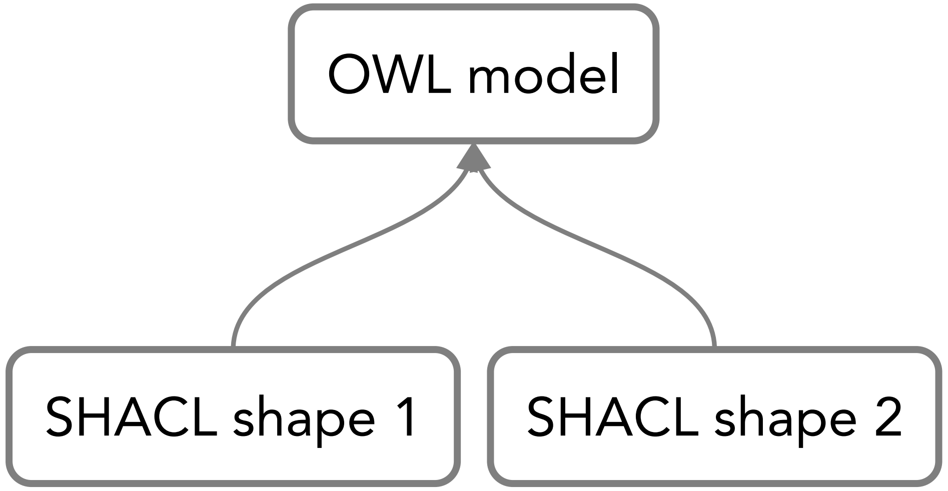
SHACL shape museum 2

Shape 11

One model, multiple shapes



This ability to define multiple SHACL shapes over the same ontology supports flexibility and interoperability, allowing different institutions to share and validate data according to their own requirements while still adhering to a common semantic foundation.



Recap so far…

Open world: missing information does not cause an error OWL

Inference for Classification: OWL

- Class definition
- Property domain and range
- Subclass relationship

Closed world: missing information causes and error SHACL

- Data Integrity: SHACL
- Data Validation: SHACL

Class composition using sh:node: SHACL
Multiple shapes for the same model: OWL + SHACL

What if want to ensure my art pieces are definitely created by an artist?

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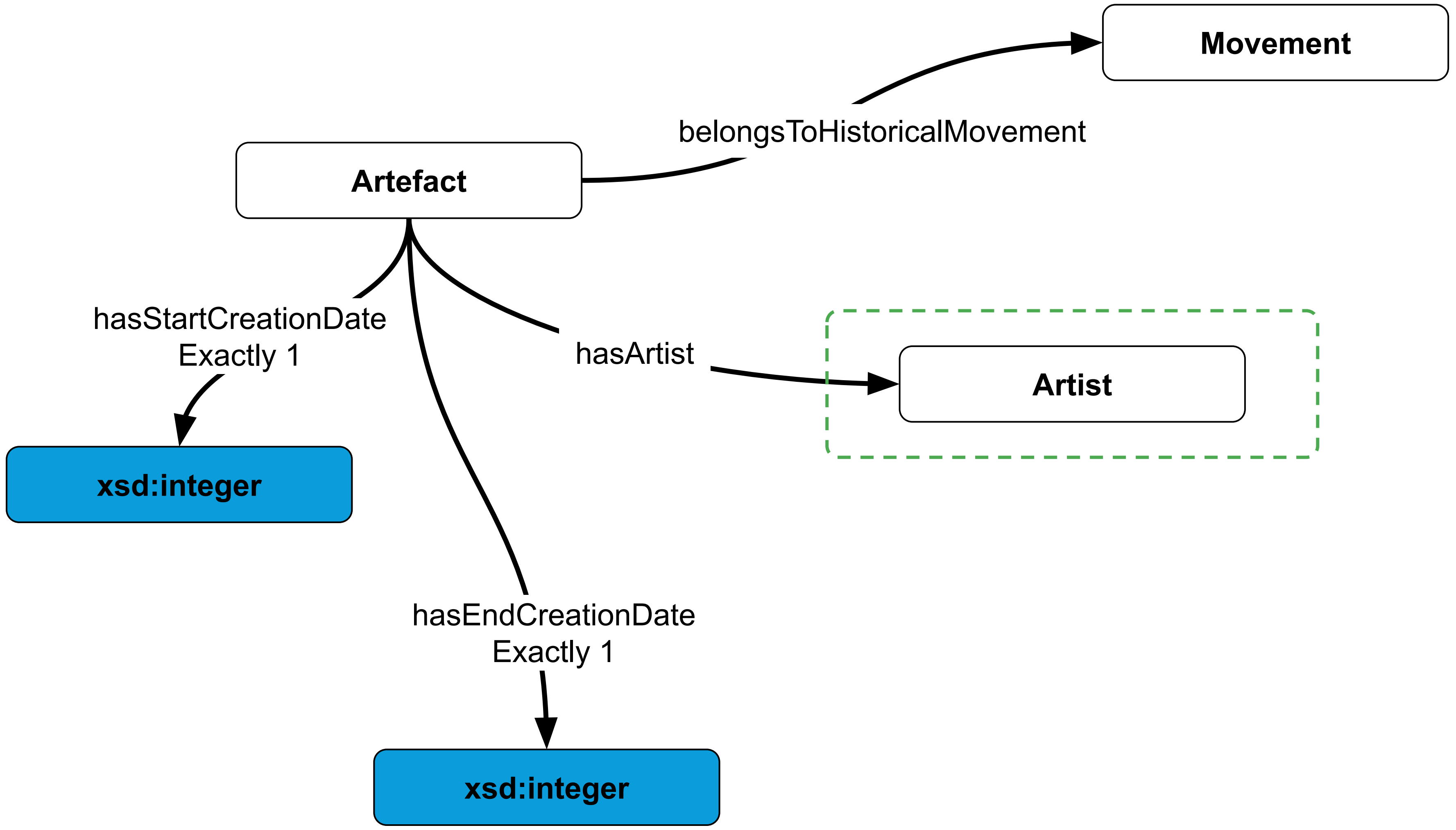
ROUND 7: Restrictions

I want to ensure every art piece is only created by an artist



Deep dive in the property definition

Can I use domain and range of ex:hasArtist?

- Open model_10.ttl
- Adding wrong artist (hasArtist Cubism)
  Or
- open model_10_wrong_artist.ttl
- Run the reasoner

RESULTS

- No error even though Cubism is wrong
- Cubism classified as an Artist! (remember inference?)

WHY? 'Violating' a domain or range constraint does not necessarily mean that the ontology is inconsistent or contains errors.

So what should we do ?

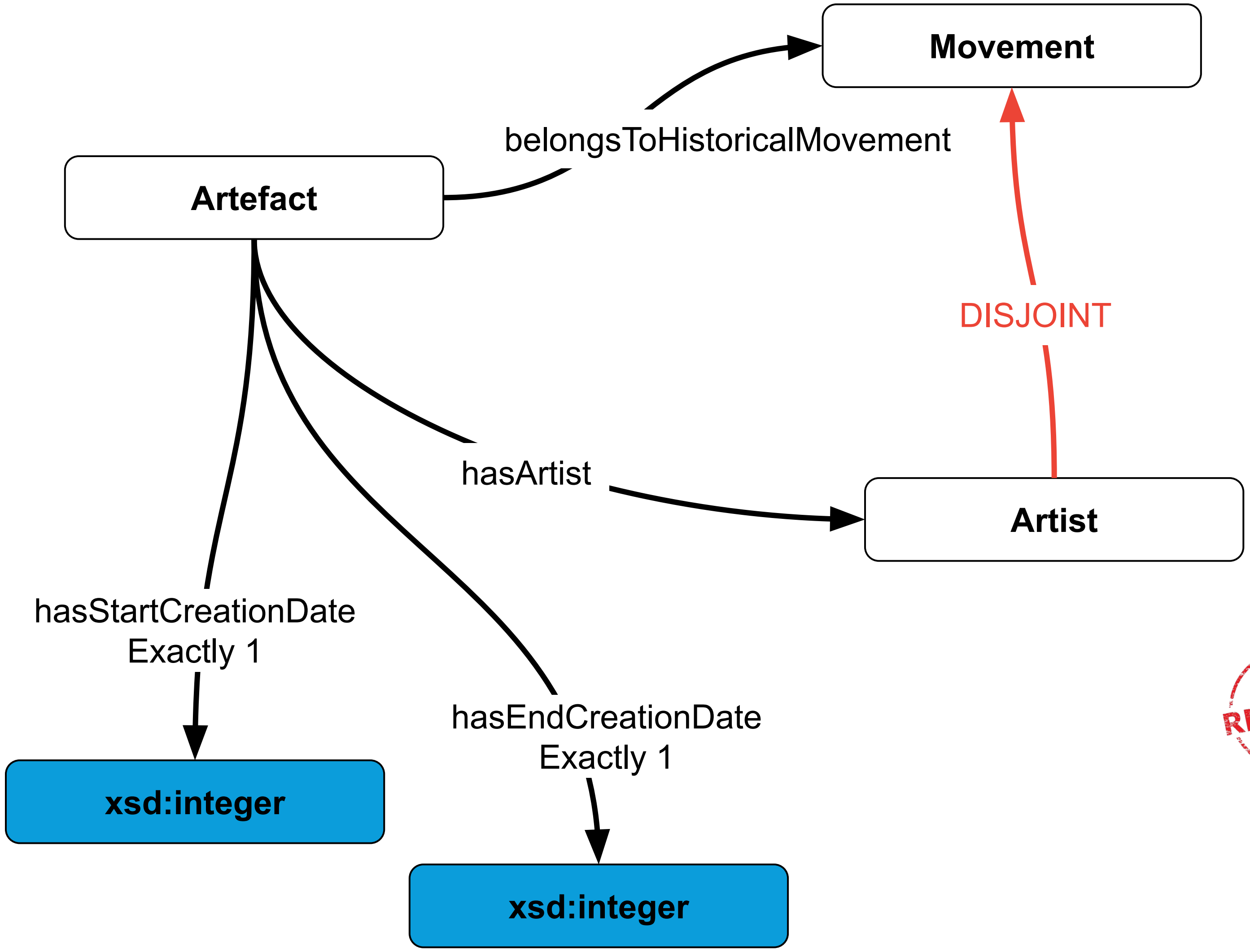
OWL solution: Define the two classes, Movement and Artist, as disjoint

Fun Fact:
The Weeping Woman, valued at A$1.6M in 1986. It was stolen from the National Gallery of Victoria by a group calling themselves the Australian Cultural Terrorists (ACT), who demanded funding for the arts and and the creation of a $25,000 annual art prize (The Picasso Ransom) or they would destroy the painting. The government refused to negotiate, and police were informed three weeks later that *The Weeping Woman* was stowed in a locker, unharmed.

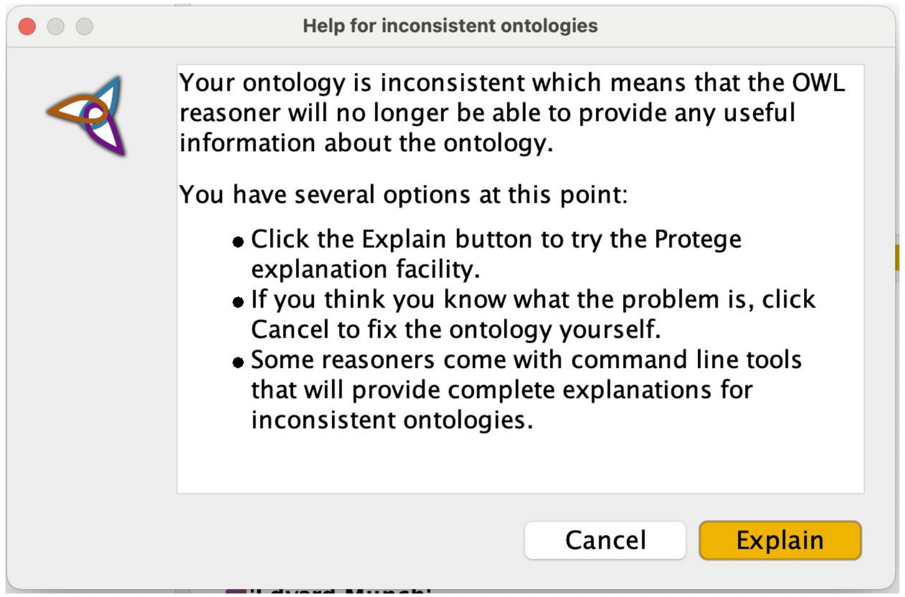
Source: wikipedia

Bloomberg

Disjoint Classes


Movement
belongsToHistoricalMovement
Artefact
DISJOINT
hasArtist
Artist
hasStartCreationDate Exactly 1
hasEndCreationDate Exactly 1
xsd:integer
xsd:integer

- Make Artist and Movement disjoint
  Or
- open model_10_disjoint.ttl
- Run the reasoner

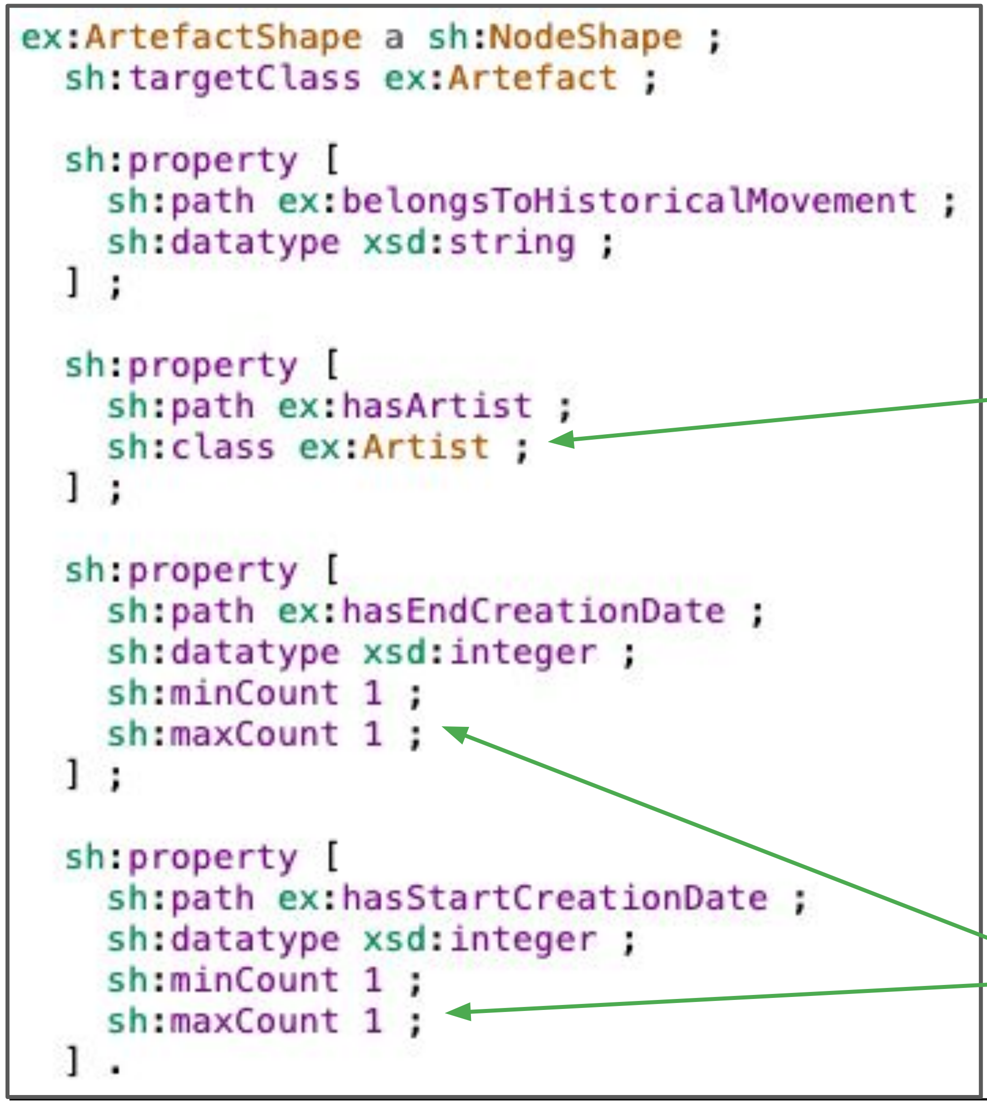

Help for inconsistent ontologies

Your ontology is inconsistent which means that the OWL reasoner will no longer be able to provide any useful information about the ontology.

You have several options at this point:

- Click the Explain button to try the Protege explanation facility.
- If you think you know what the problem is, click Cancel to fix the ontology yourself.
- Some reasoners come with command line tools that will provide complete explanations for inconsistent ontologies.

Defining Restrictions on your data with SHACL



```
ex:ArtefactShape a sh:NodeShape ;
  sh:targetClass ex:Artefact ;

  sh:property [
    sh:path ex:belongsToHistoricalMovement ;
    sh:datatype xsd:string ;
  ] ;

  sh:property [
    sh:path ex:hasArtist ;
    sh:class ex:Artist ;
  ] ;

  sh:property [
    sh:path ex:hasEndCreationDate ;
    sh:datatype xsd:integer ;
    sh:minCount 1 ;
    sh:maxCount 1 ;
  ] ;

  sh:property [
    sh:path ex:hasStartCreationDate ;
    sh:datatype xsd:integer ;
    sh:minCount 1 ;
    sh:maxCount 1 ;
  ] .
```

- Open Shape 12
- Change the value of the scream ex:hasArtist to cubism

This restricts the values of ex:hasArtist to Class Artist

RESULTS

Error ! restricting the range of ex:hasArtist to the class Artist throws an error when any other value is defined as the range in the data graph

This ensure that every Painting has exactly 1 Start and End Creation Date

SHACL Restrictions

Restrictions

String Based

- sh:minLength
- sh:maxLength
- sh:pattern
- sh:languageIn
- sh:uniqueLang

Shape Based

- Node Shape
- Property Shape

Value Type

- sh:Class
- sh:datatype
- sh:nodeKind

Value Range

- sh:minExclusive
- sh:maxExclusive
- sh:minInclusive
- sh:MaxExclusive

Cardinality

- sh:minCount
- sh:maxCount

Logical

- sh:not
- sh:and
- sh:or
- sh:xone

Property Pair

- sh:equals
- sh:disjoing
- sh:lessThan
- sh:lessThanOrEauals

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Closed world: missing information causes and error SHACL

- Data Integrity: SHACL
- Data Validation: SHACL
  - Restrictions/Constraints for Validation: SHACL

Class composition using `sh:node`: SHACL

Multiple shapes for the same model: OWL + SHACL

Tara

ROUND 8: Inference

Inference for New (implicit) Knowledge

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Inferring New Knowledge

You have the historical movement for your artefacts, does that allow you to also know which artist belongs to what movement?

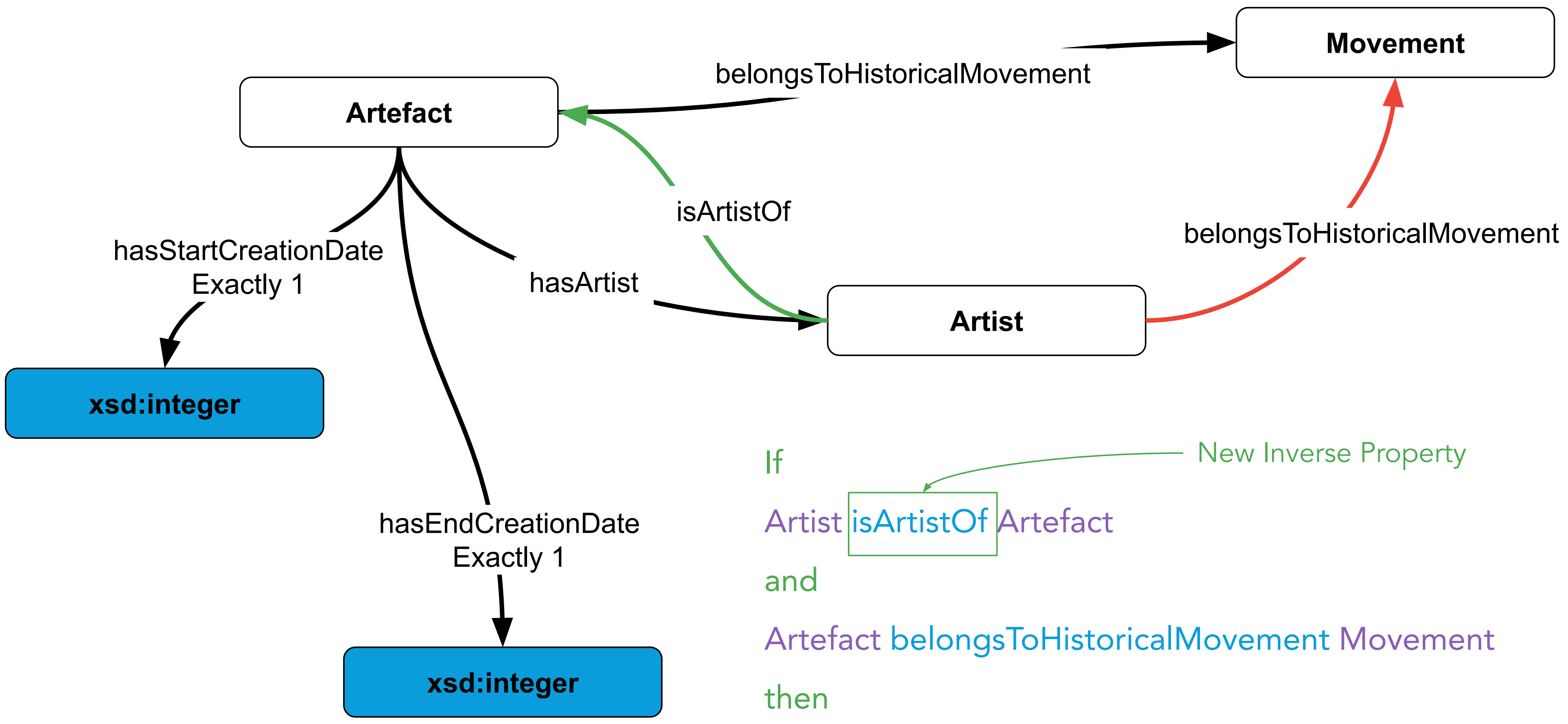
- Open model_11.ttl
- Run the query 3.1

```
SELECT DISTINCT ?Artist ?Movement
WHERE {
   ?Artist a ex:Artist ;
     ex:belongsToHistoricalMovement ?Movement .
}
```

RESULTS Nothing!

Possible solution: Property Chain

The Model extended even more!



New Inverse Property

If

Artist isArtistOf Artefact

and

Artefact belongsToHistoricalMovement Movement

then

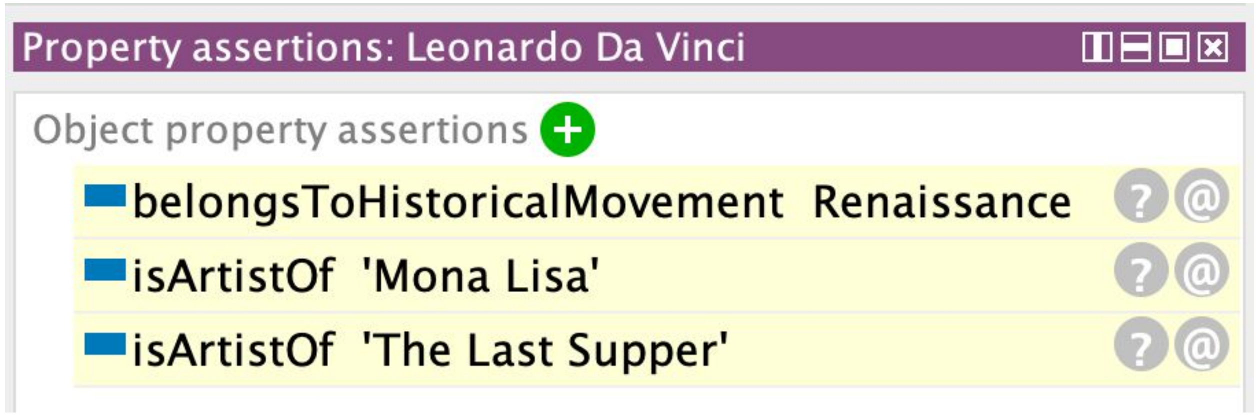
Artist belongsToHistoricalMovement Movement

Inverse Properties in OWL

- First, add isArtistOf inverse property
- Implement the property chain

  Or
- load model_12.ttl
- Run the reasoner

RESULTS Reasoner infers the implicit Knowledge



Property assertions: Leonardo Da Vinci

Object property assertions

belongsToHistoricalMovement Renaissance

isArtistOf 'Mona Lisa'

isArtistOf 'The Last Supper'

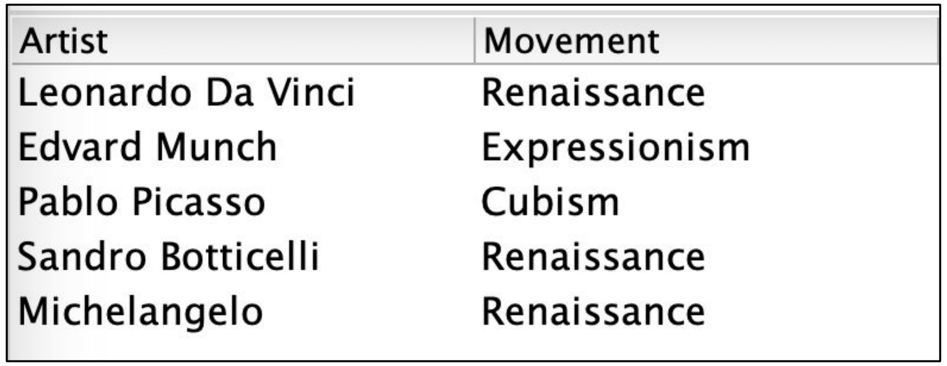
Property chain in OWL (owl:propertyChainAxiom)

- Save the new inferred data

  Or
- upload model_12_inferred.ttl
- Then run the query 3.1 again

```
SELECT DISTINCT ?Artist ?Movement
WHERE {
   ?Artist a ex:Artist ;
     ex:belongsToHistoricalMovement ?Movement .
}
```

RESULTS



Artist	Movement
Leonardo Da Vinci	Renaissance
Edvard Munch	Expressionism
Pablo Picasso	Cubism
Sandro Botticelli	Renaissance
Michelangelo	Renaissance

Inferring New Knowledge

Considering that you know the museum in which the piece is exhibited, can you answer questions like:

Give me all the pieces that are located in a country (i.e., Italy)?

In order to answer to questions like this, we need to add further knowledge into our KG:

If

Artefact *isExhibitedIn* Premises

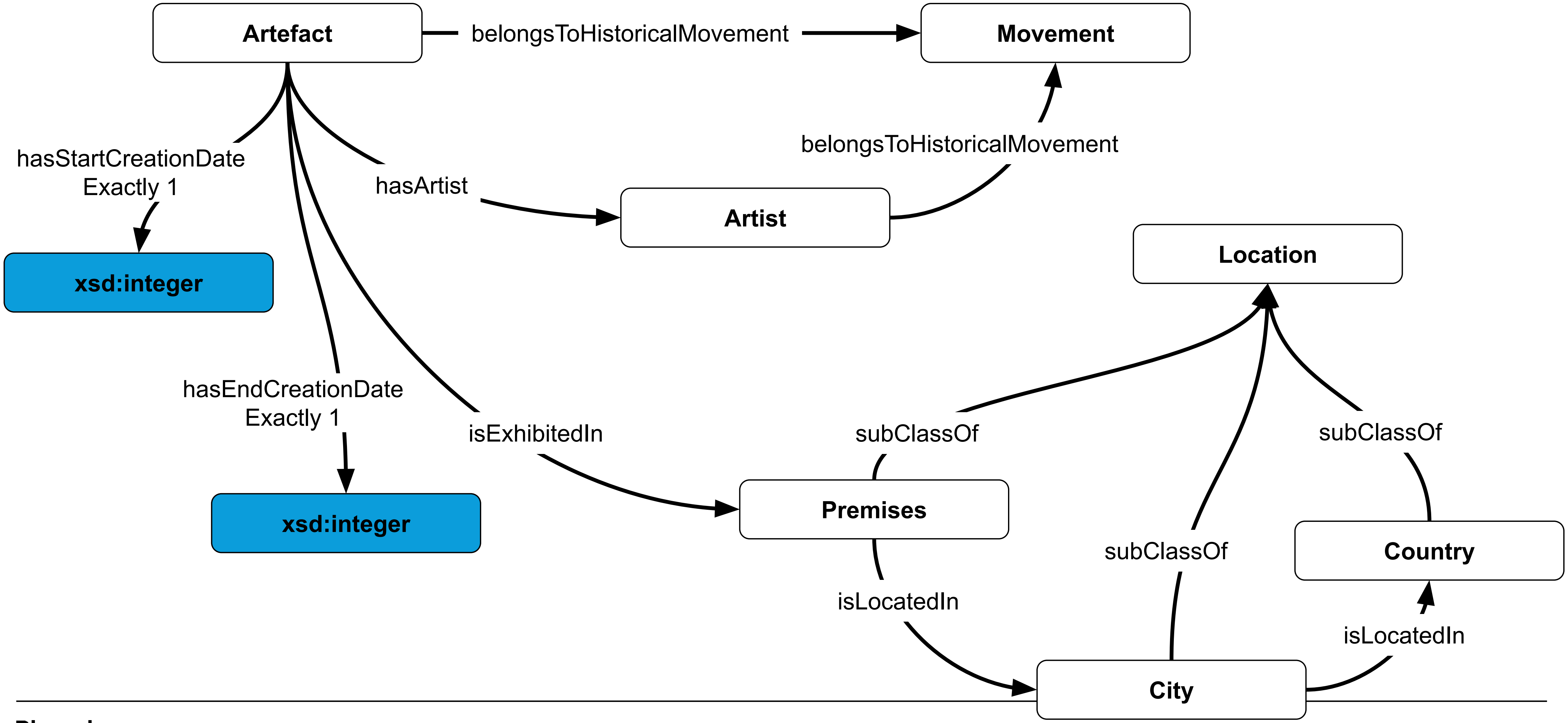
and

Premises *isLocatedIn* City

then

Artefact *isLocatedIn* City

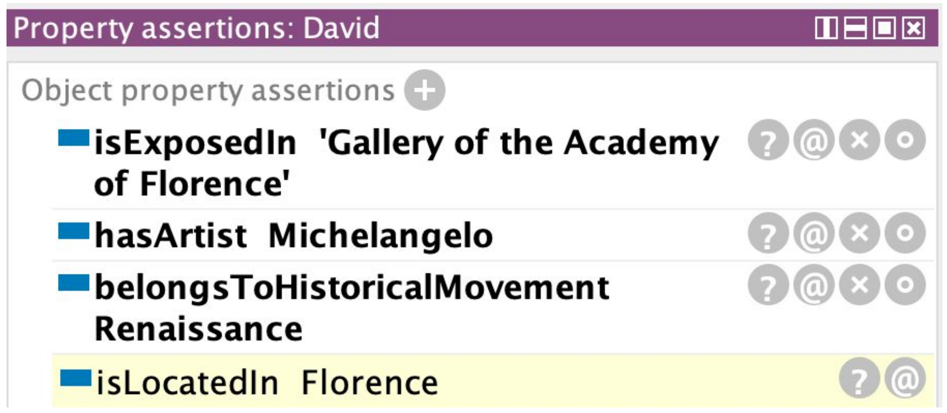
The model extended even more!



Inferring New Knowledge

- Add new classes and the property chain
  Or
- Load model_13.ttl
- Run reasoner

Reasoner infers the implicit Knowledge based on property chain definition


Property assertions: David

Object property assertions

isExposedIn 'Gallery of the Academy of Florence'

hasArtist Michelangelo

belongsToHistoricalMovement Renaissance

isLocatedIn Florence

- Save the new inferred data
  Or
- Upload model_13_inferred.ttl
- Run query 3.2

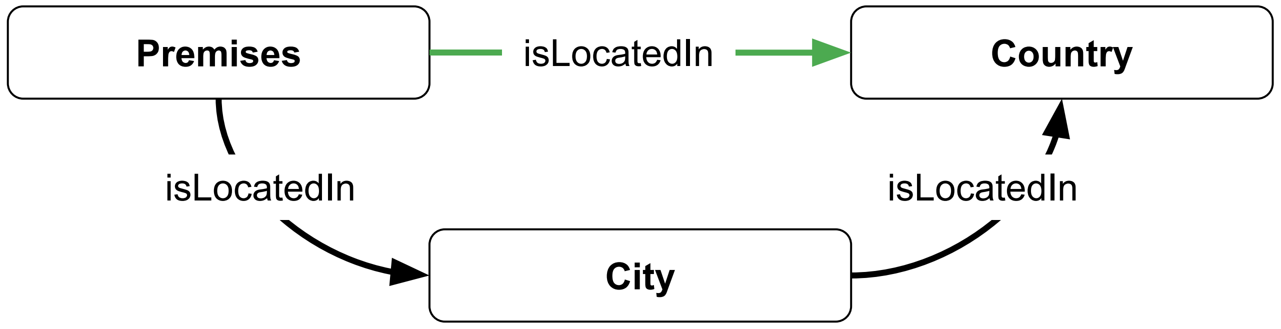
```
SELECT DISTINCT ?Artefact
WHERE {
?Artefact a ex:Artefact ;
ex:isLocatedIn ex:italy .
}
```

Nothing!
Why? We are still missing the country

Transitivity in properties for inference of New Knowledge

How can we ensure that if something is located in a city then that something is located in the country of that city?

Transitivity automatically infers that if a property links A → B and B → C, then A → C for that same property so we can say



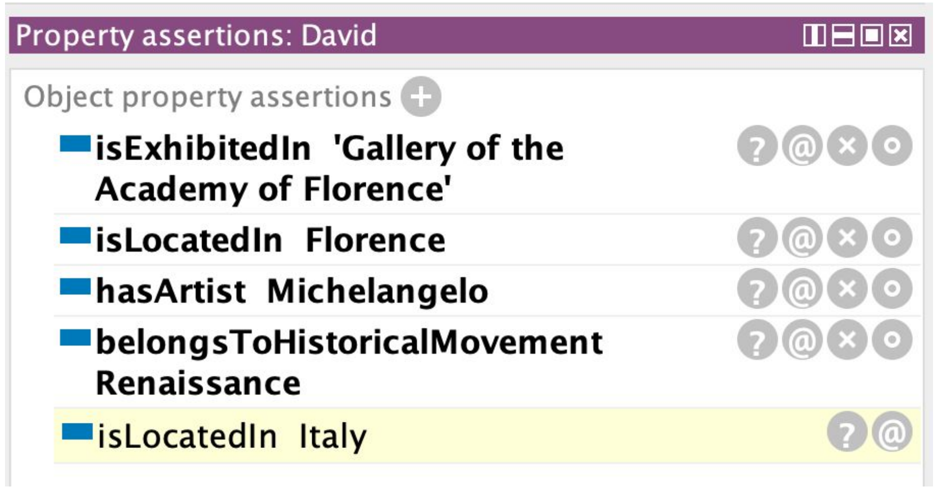
owl:propertyChainAxiom allows defining a new property that results from a sequence of different properties (e.g., A → B via isExhibitedIn and B → C via isLocatedIn ⇒ A → C via isLocatedIn).

isLocatedIn is transitive property. Then Artefact isLocatedIn Country

Transitivity in properties for Inference of New Knowledge

- Make isLocatedIn transitive
  Or
- Open model_14.ttl
- Run reasoner

Reasoner infers the implicit Knowledge based on property chain definition and transitivity


Property assertions: David

Object property assertions

isExhibitedIn 'Gallery of the Academy of Florence'
isLocatedIn Florence
hasArtist Michelangelo
belongsToHistoricalMovement Renaissance
isLocatedIn Italy

- Save the new inferred data
  Or
- upload model_14_inferred.ttl
- Run query 3.2 again

```
SELECT DISTINCT ?Artefact
WHERE {
?Artefact a ex:Artefact ;
ex:isLocatedIn ex:italy .
}
```

You can now see all artefacts located in Italy

Recap so far…

Open world: missing information does not cause an error OWL

Closed world: missing information causes and error SHACL

- Data Integrity: SHACL
- Data Validation: SHACL
  - Constraints for Validation: SHACL

Inference for Classification: OWL

- Class definition
- Property domain and range
- Subclass relationship

Inference for new/implicit knowledge: OWL

Multiple shapes / data behaviors for the same model: OWL + SHACL

The Material Example

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ROUND 9: Range Restrictions

The Material Example

What are the materials used to make this artefact?

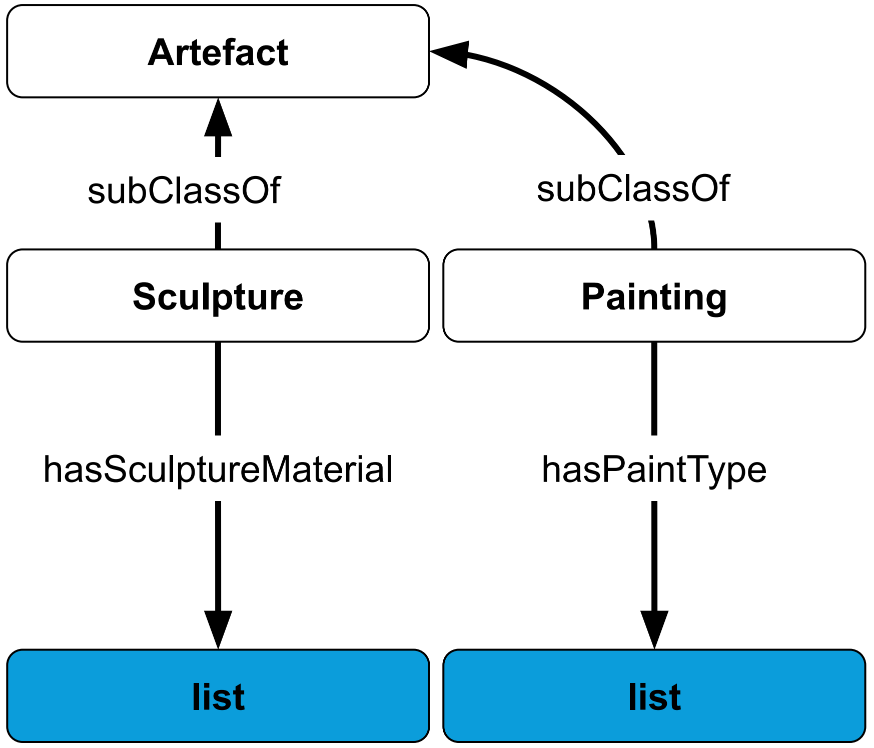
You also want to ensure that the range of allowed materials is previously captured.

Let's start with the model: model_15.ttl

Choice 1: use owl dataproperty and a list as the range

Challenge:

- What if you want to say something more about each material? Like its origin or consistency?



The Material Example

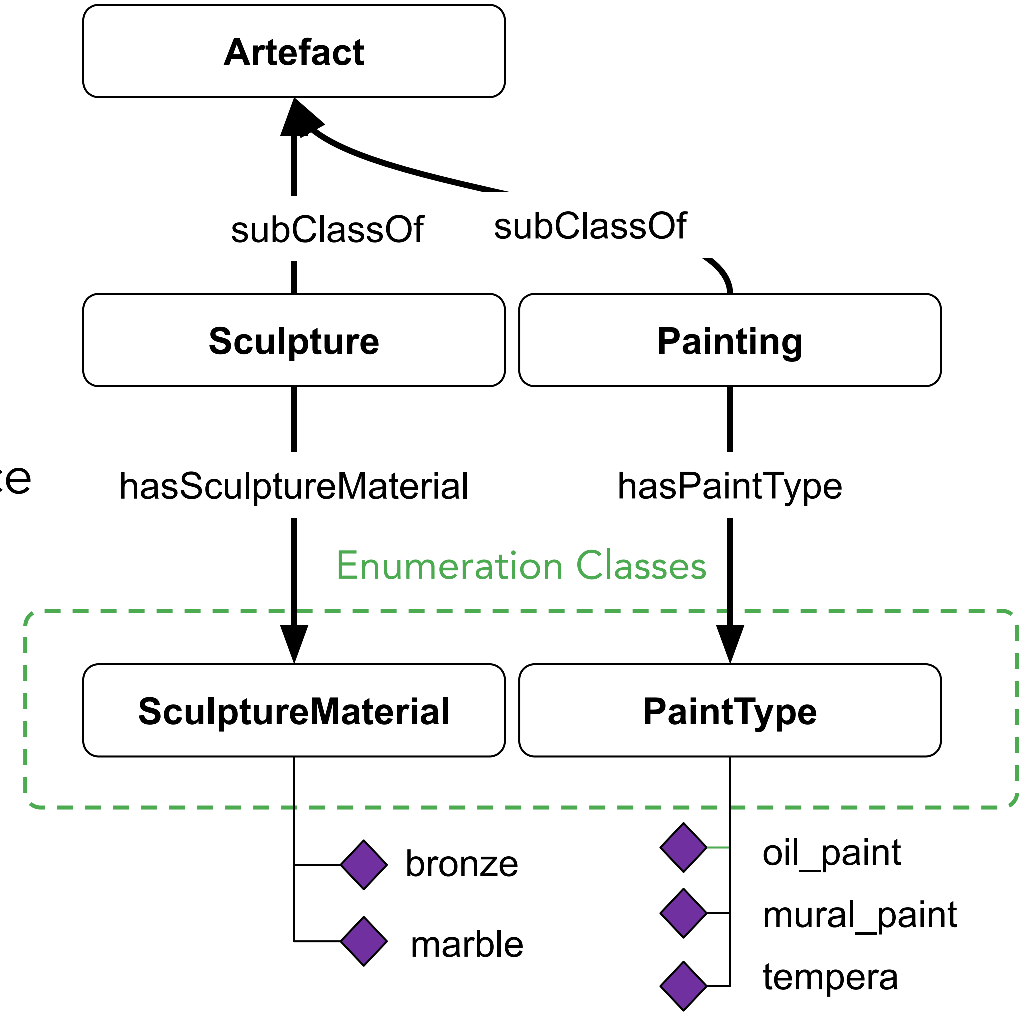
What are the materials used to make this artefact?

Choice 2: Use OWL Enumeration class

- Load model_16.ttl
- Add the following wrong data
  ex:weapingWoman ex:hasPaintType ex:florence
- Run reasoner

No Error!
Reasoner infers that florence is a member of *PaintType* class

WHY? Because of OWL's OWA



The Material Example

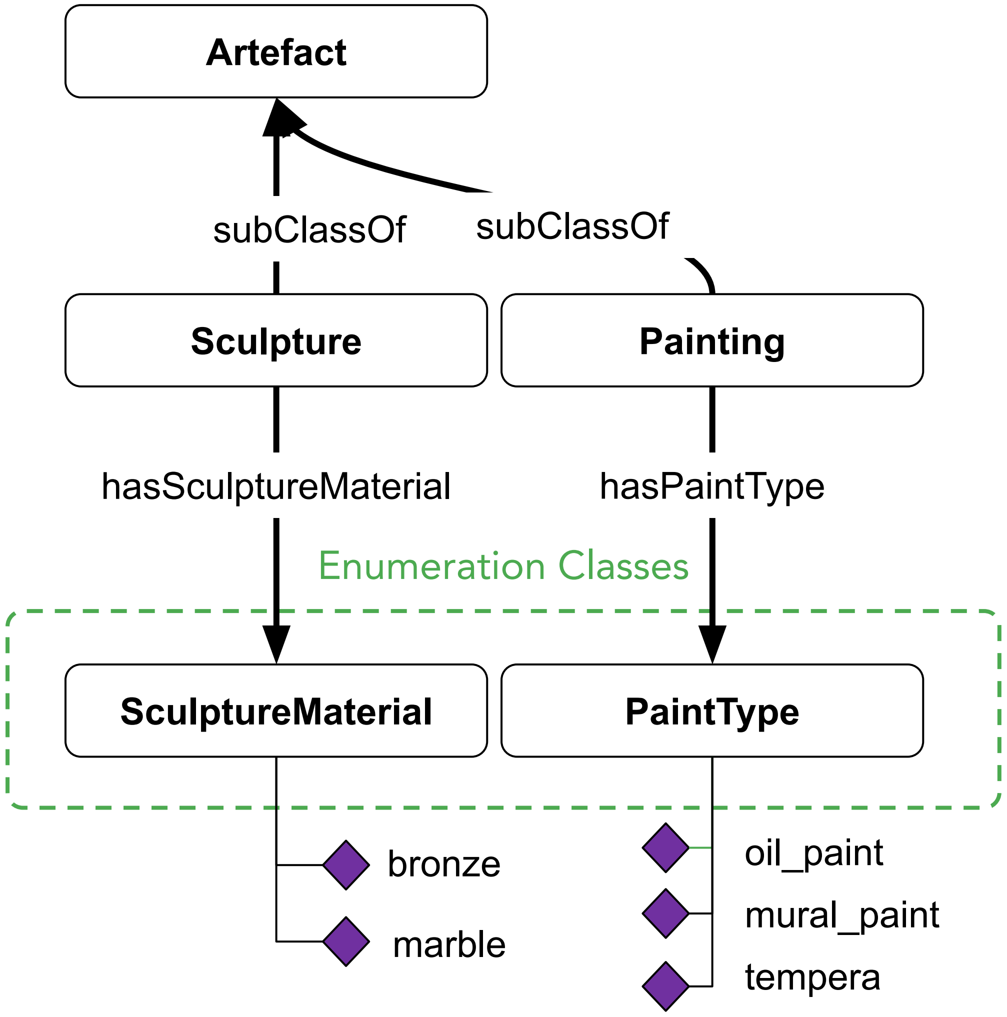
What are the materials used to make this artefact?

Choice 2: Use OWL Enumeration class

- What if we limit the range of *hasPaintType* to only one *PaintType*?
- Making the property hasPaintType Functional

No Error!
Reasoner infers that the instances are the same!

WHY? OWL does not support UNA



Unique Name Assumption

In logics with UNA, different names always refer to different entities in the world

OWL does NOT support UNA

Consequences:

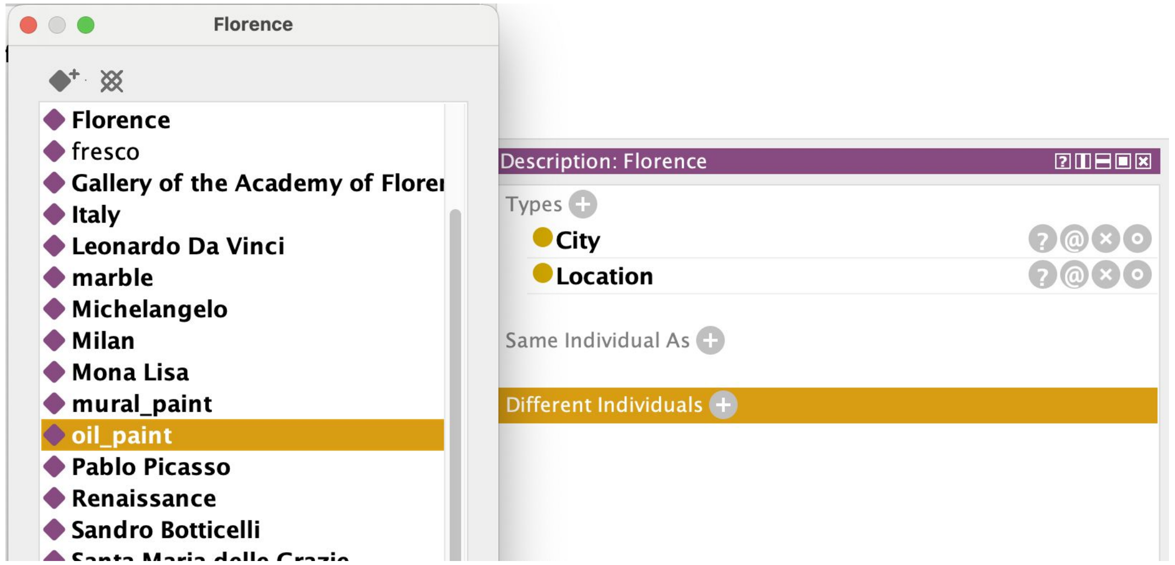
- Different entities have to be declared to be different (otherwise, they are potentially identical) - owl:differentFrom, owl:disjointWith
- Identical entities also have to be declared to be identical (otherwise, they are potentially different) - owl:sameAs, owl:equivalentClass

Can we still solve this with OWL?

Yes, but…

The property hasPaintType needs to be Functional

The instances need to all be defined as owl:differentFrom



Florence

- Florence
- fresco
- Gallery of the Academy of Flore
- Italy
- Leonardo Da Vinci
- marble
- Michelangelo
- Milan
- Mona Lisa
- mural_paint
- oil_paint
- Pablo Picasso
- Renaissance
- Sandro Botticelli

Description: Florence

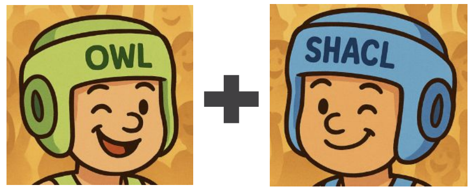
Types
- City
- Location

Same Individual As

Different Individuals

Too much work!

There's a better solution :)



The Material Example

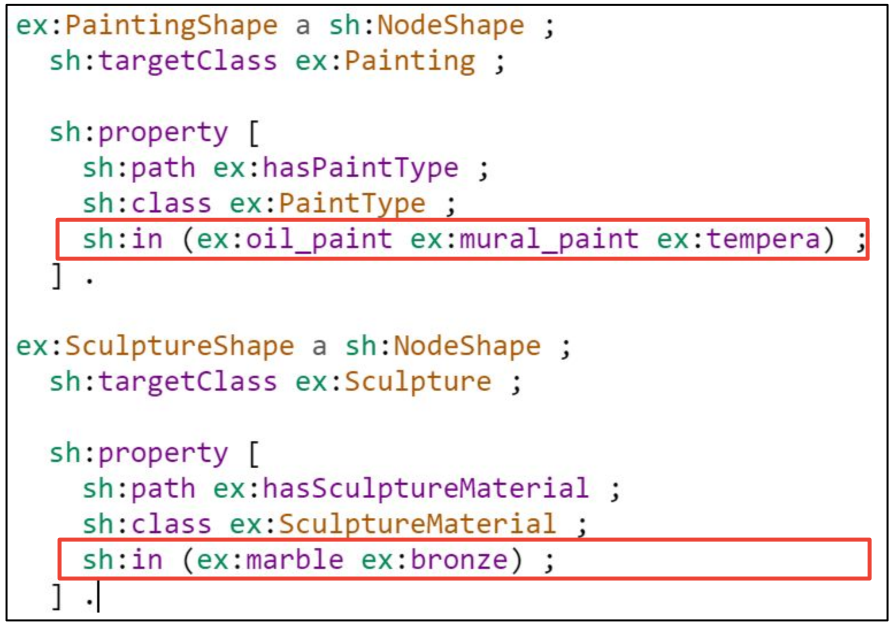
What are the materials used to make this artefact?

Choice 3:

- Use OWL enumeration classes & SHACL shapes to restrict the range of artefacts Shape 13

Pros:

- no diff definition
- no wrong class inference
- easy expansion of material types
- Easy addition of information about material

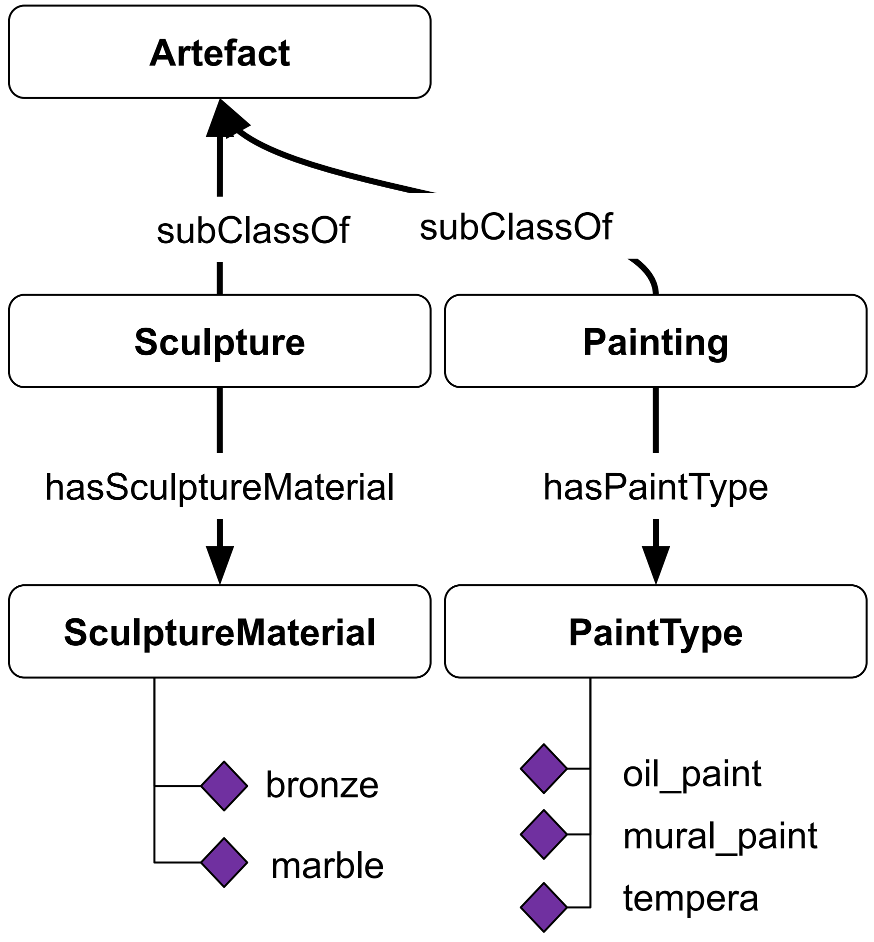


```
ex:PaintingShape a sh:NodeShape ;
  sh:targetClass ex:Painting ;

  sh:property [
    sh:path ex:hasPaintType ;
    sh:class ex:PaintType ;
    sh:in (ex:oil_paint ex:mural_paint ex:tempera) ;
  ] .

ex:SculptureShape a sh:NodeShape ;
  sh:targetClass ex:Sculpture ;

  sh:property [
    sh:path ex:hasSculptureMaterial ;
    sh:class ex:SculptureMaterial ;
    sh:in (ex:marble ex:bronze) ;
  ] .
```



Full Recap

Open world: missing information does not cause an error OWL

Inference for Classification: OWL

- Class definition
- Property domain and range
- Subclass relationship

Inference for new/implicit knowledge: OWL

Closed world: missing information causes and error SHACL

- Validation for Data Integrity: SHACL
  - Constraints for Validation: SHACL

Multiple shapes for the same model: OWL + SHACL
Mix of Inference and Validation: OWL + SHACL

Final Round: ?

No round just a fun fact …

And the winner is.................

Bloomberg

WINNER :YOU

Disclaimer: Created by ChatGPT

- Identify and understand the true problem you are trying to solve
- Understand the strengths and weaknesses of each technology and why and what it's built for
- Choose the right tooling and understand the strengths of your tool
- Based on the above KNOWLEDGE infer the RIGHT CHOICE !

Questions ?

Thank you!

Let's discuss more

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