

# Exploring Industry 4.0 Standards with the Ontotext Platform

Semantics 2020 vendor videos

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## Intro

- Hi, my name is Vladimir Alexiev and I'm Ontotext's Chief Data Architect.
- Miroslav Chervenski who is the Ontotext Platform Product Manager also contributed to this presentation.

In our work with Industry data, we have researched a number of industrial data standards. This presentation is an intro to the Industry 4.0 Knowledge Graph by Fraunhofer IAIS and how we used the Ontotext Platform for simplified access and exploration of this KG.

Key resources (more links further in the slides):

- My publications: <http://rawgit2.com/VladimirAlexiev/my/master/index.html>
- This presentation: <http://rawgit2.com/VladimirAlexiev/my/master/pres/20200908-i40kg-semantics/Slides.html>
- Industry 4.0 KG main visualization: <http://i40.semantic-interoperability.org/> (29-Mar-2024: site is down)
- Ontotext Platform Semantic Objects: <https://platform.ontotext.com/semantic-objects/>
- Try GraphQL queries: <https://i40kg.ontotext.com/workbench/graphql>
- Try SPARQL queries: <https://i40kg.ontotext.com/graphdb/sparql>

## Industry Standards

- Numerous “traditional” standards for design, manufacturing, automation, control, quality etc
- New and upcoming standards for Industry 4.0, digital twins, Industrial IoT, asset management, etc

- The standards landscape is large and puzzling, how can one understand it?

Standard classification frameworks:

- [Current Standards Landscape for Smart Manufacturing Systems](#), NISTIR 8107, NIST, 2016-02
- [The Industrial Internet of Things. Volume G1: Reference Architecture. IIRA v1.9](#), Industrial Internet Consortium, 2019-06
- Reference Architectural Model Industrie 4.0 (RAMI 4.0), German Electrical and Electronic Manufacturers' Association (ZVEI)
- Asset Administration shell, German Electrical and Electronic Manufacturers' Association (ZVEI)

## Notes on Standards

Standards have always been very important in the industrial society.

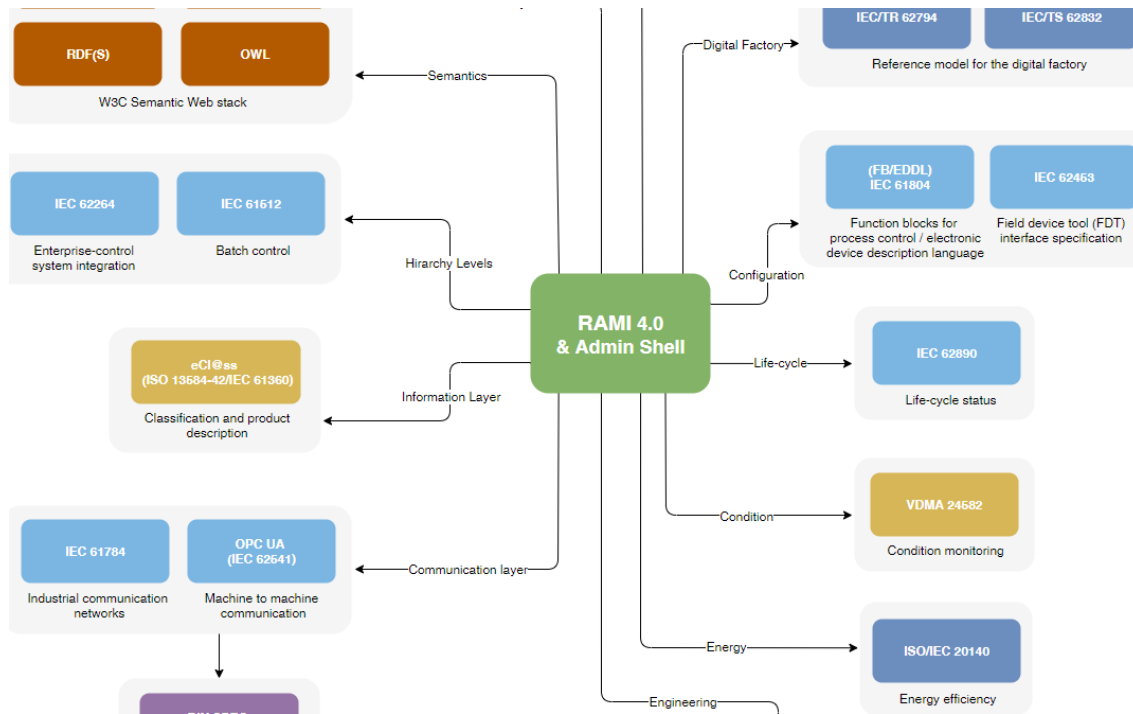
- In addition to old established standards, there are now new upcoming standards for the digitization of industry (Industry 4.0).
- Various classification frameworks have been adopted. Some of the important ones include NIST, IIRA, RAMI and Asset Shell.
- Asset Shell is also a methodology/idea about integrating various standards in one “shell” using semantic technologies.

## Industry 4.0 Knowledge Graph (I40KG)

(formerly Standards Ontology), Fraunhofer IAIS

- Describes semantically 320 standards, their classification, area of use, purpose, relations, etc
- Documentation: <https://i40-tools.github.io/I40KG/docs>
- Main visualization: <http://i40.semantic-interoperability.org/>
- Extra visualizations: <https://i40-tools.github.io/StandardOntologyVisualization/>
- [The Industry 4.0 Standards Landscape from a Semantic Integration Perspective](#), Emerging Technologies and Factory Automation (ETFA), 2017-09
- Classifies standards according to various methodologies and levels: Admin Shell Sub Model, Alliance of Industrial Internet Architecture Classification, Fiware Chapter, IDS RAM Layer, IIRA Functional Domain, ISA 95 Level, IVI Layer, IoT-A Perspective, NGSI Context Information Management API, Product Development Life Cycle, Production System Life Cycle, RAMI Hierarchy Level, etc

## I40KG Main Visualization



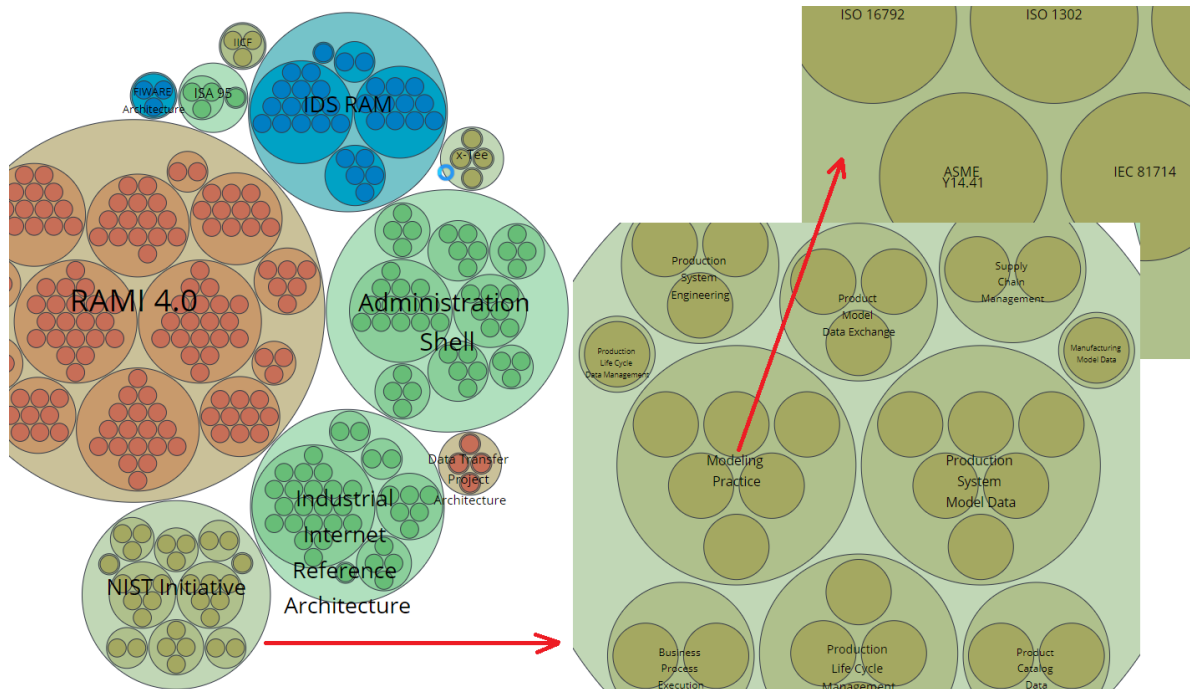
## I40KG Visualization Notes

The main view of I40KG shows the integrative role of RAMI 4.0 and Admin Shell, their various areas, and how they build upon existing areas in those areas.

- For example for Communication Layer, they use OPC UA (for M2M communication) and IEC 61784 (for industrial networks).
- Click on the title for a full version of the image!

## I40KG Standards Classification

[Standards Classification visualization](#): “progressive zoom”



## I40KG Standards Progressive Classification

A great feature of I40KG is its elaborative (progressive) classification. (Follow the direction of the red arrows).

- On the top level are about 10 framework architectures or classification initiatives.
- On the middle level, eg the NIST initiative covers Modeling, Production model data, Production lifecycle management, etc.
- On the lowest level, eg Modeling includes standards like ASME Y14.41, IEC 81714, etc

## I40KG Concerns

- “Concerns” are various areas or topics relevant to industry digitization (eg AI, access rights, adaptability, etc).
- Addresses about 160 Concerns

AI AccessPolicy Access\_Rights\_for\_IoT-Cloud Accountability Actuation Adaptability Agility Anonymity AssetManagement Authentication Authorization Auto\_Scaling AutonomousCommunication AutonomousConfiguration Availability Awareness Bandwidth BigDataApplications BusinessContext BusinessProcessManagement BusinessTransactions BusinessValue CardinalityOfDataSources CardinalityOfParticipants Certification CloudComputing Communication ComplexEventProcessing Compliance Confidentiality Connectivity

ConstrainedDevices ContextAwareness CostEfficiency CrossDomainIdentityManagement  
Customization DataAccess DataAccessControl DataAggregation DataAnalytics

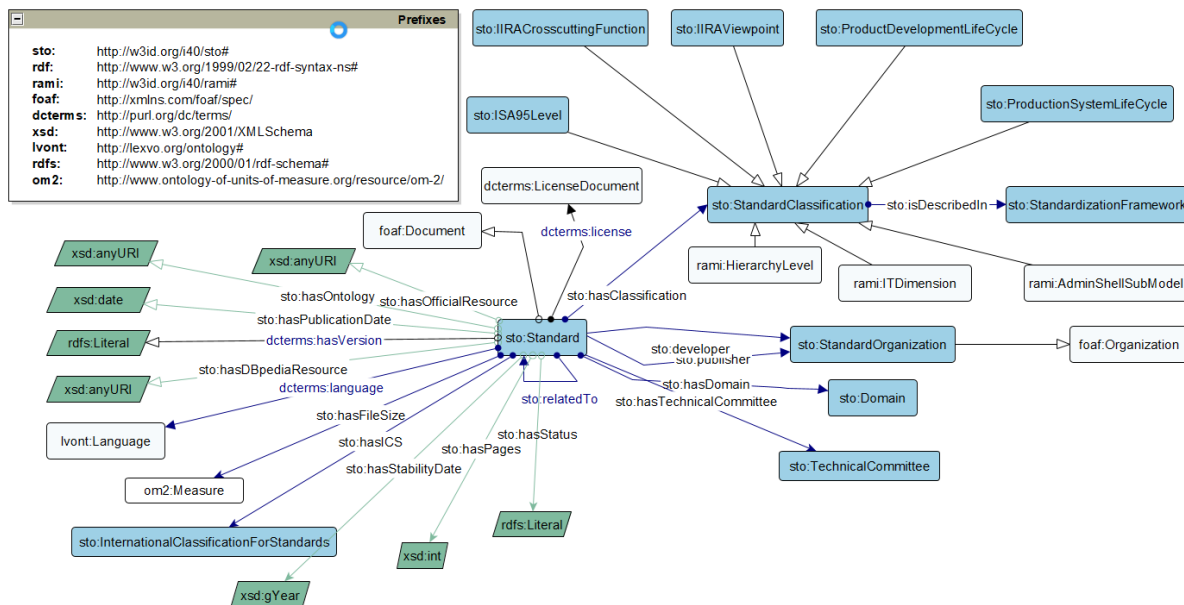
...

ServiceChoreography ServiceComposition ServiceDeployment ServiceDescription ServiceDiscovery  
ServiceIsolation ServiceLevelAgreements ServiceLifecycleManagement ServiceOrchestration  
ServiceSelection Service\_Recovery Software\_Updates SpatialModeling StreamProcessing  
SyntacticInteroperability SystemEvolution SystemRecovery ThingDescription ThingMobility  
ThingRepresentation TimeSynchronization Trustworthiness Unicast UnreliableNetwork  
UserInteraction UserPreferences VendorLockin VirtualEntity

## I40KG Model (Described)

- So, how do we use this wealth of semantic data?
- We need to understand its model: what ontologies it uses and how they are put together.
- The paper [The Industry 4.0 Standards Landscape from a Semantic Integration Perspective](#) at ETFA 2017 provides a good description, and the basic data looks like this.

## I40KG Model Image (Described)

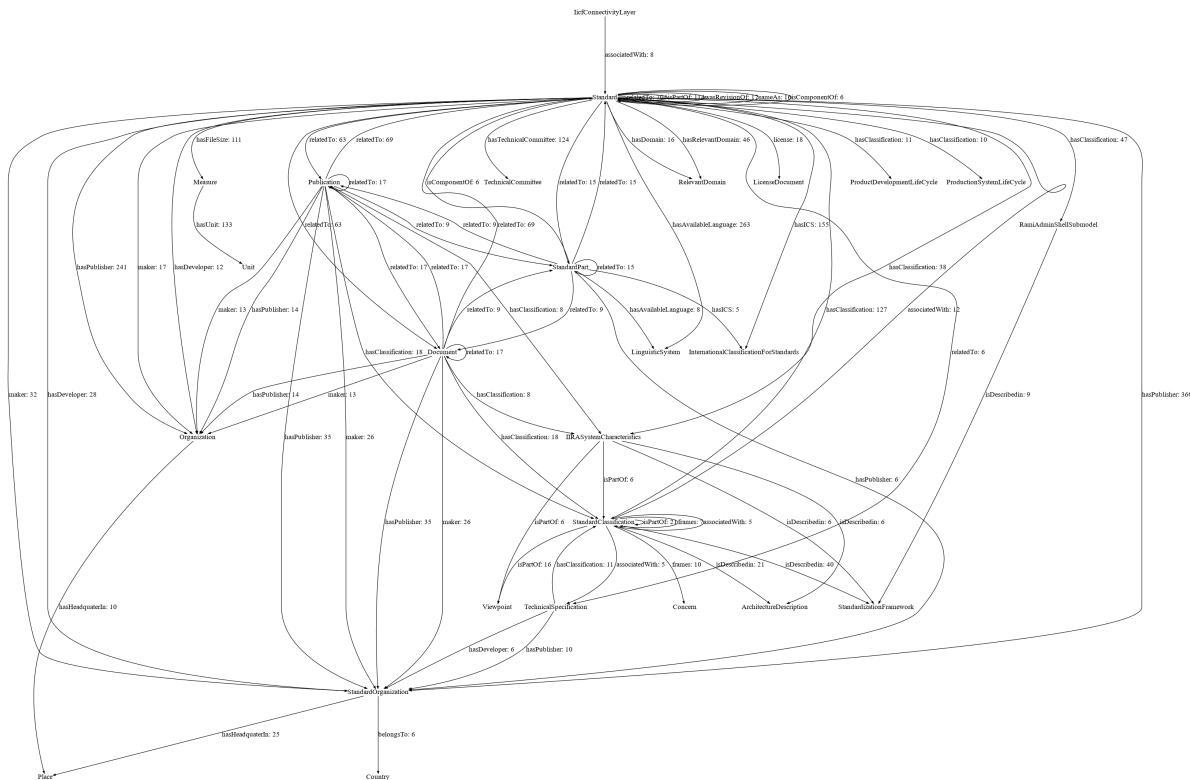


### I40KG Model (Actual)

In reality, the data is a lot more complex.

- If you analyze all relations between classes, there are 300 **domain-property-range**
- Here we depict relations with  $\geq 5$  instances; there are 78 total relations
- Note: attributes are not even depicted.
- Click on the title for a large version of the diagram.

### I40KG Model Image (Actual)

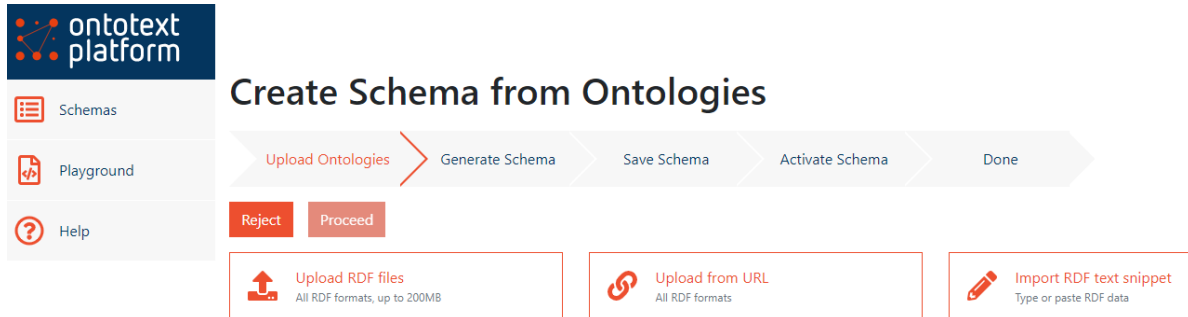


## Exploring With the Ontotext Platform

The [Ontotext Platform](#) gives us an easier way to explore: GraphQL.

- We need to make a Semantic Object model schema (SOML).
- Made various fixes to ontology (eg duplicated prop definitions, redundant props) and data (eg `dbr:_Arizona` shouldn't have leading underscore)

- First generate a draft schema from the ontology using a tool called **owl2sowl**, which is embedded in the Workbench in the form of a wizard
- Generated **Semantic Object (SOWL) Model** from the ontology with **owl2sowl** (see [github](#)): Schema>Create wizard



## SOWL Schema

Made a number of additions and fixes, eg

- **lang: en,ALL** to return only one exemplar of multi-valued labels (preferring English),
- removing almost all prefixes from GraphQL names for easier consumption (eg **associatedWith** instead of **dul:associatedWith**),
- adding **virtual inverses with inverseAlias** for bidirectional graph navigation,
- binding all useful props to classes (several are in an abstract root class Entity),
- removing **max: inf** cardinality from several props since it's more expensive to query,

## SOML Schema Activated

The screenshot shows the Ontotext Playground interface. On the left is a sidebar with 'Schemas', 'Playground', and 'Help' options. The main area displays the 'Industry 4.0 Knowledge Graph' schema. Below the title are 'Validate', 'Update', and 'Download' buttons. A code editor shows the SOML schema definition for 'i40kg'. Below the editor, the 'i40kg Schema' is listed with 'Edit', 'Upload new version', 'Download', 'Activate', and 'Delete' buttons. Three panels provide details: 'Schema Metadata' (ID, Label, Creator), 'Schema Information' (Objects, Properties, Roles), and 'Dataset statistics' (Measure, XPathSelector, SpecificResource, RangeSelector, InternationalClassificationForStandards, StandardClassification, RelevantDomain).

**Schema Metadata**

ID	/soml/i40kg
Label	Industry 4.0 Knowledge Graph
Creator	http://data.semanticweb.org/person/steffen-lohmann, https://w3id.org/i40/sto#sebastian, https://w3id.org/i40/sto#sebastian, https://www.linkedin.com/in/paul-baptiste-601177b2; fixed by Vladimir Alexiev (Ontotext)

**Schema Information**

<b>Objects: 65</b>
Interfaces: 7
Concrete objects: 58
<b>Properties: 151</b>
Data properties: 122
Object properties: 29
<b>Roles: 0</b>

**Dataset statistics**

Measure	133
XPathSelector	96
SpecificResource	51
RangeSelector	48
InternationalClassificationForStandards	26
StandardClassification	26
RelevantDomain	24

## GraphQL Query 1: Standards and Classifications

- The Platform uses the SOML definition to generate GraphQL schema, query and mutation framework, transpile to SPARQL, format results as JSON, generate SHACL for validation, etc.
- GraphQL queries practically write themselves! (Due to schema introspection)

Eg “give me standards that have both International Classification of Standards (**hasICS**) and some classifications that have both **isDescribedin** and **associatedWith** relations”

```
query Standards {  
  standard(where:{hasICS:{  
    hasClassification:{isDescribedin:{} associatedWith:{}} limit:10) {  
    label{value}  
    hasPublisher{orgName{value}}  
    hasICS{title{value}}  
    hasClassification{id  
      isDescribedin{id}  
      associatedWith{id}
```



```

    }
  }
}

```

## GraphQL Query 1 Notes

To understand this query, you need to look at the diagram of the data, and know two things:

- empty brackets in **where** mean **exists**,
- `{value}` is needed to get to the string value of a `langString`. (STO has tagged all strings as `@en`, I guess in hopes to one day expand to the whole world!).

If you play with GraphiQL, you may agree that queries nearly “write themselves”. You need a fairly precise schema though:

- Eg here I’ve put too many props in Entity (eg abbreviation, label, license) while in actuality some appear at more specific classes.
- So these props are offered for most entities, which “pollutes” the editor suggestions a bit.

## GraphQL Result 1: Standards and Classifications

(Brackets compressed and empty arrays skipped for brevity)

```

"standard": [{
  "label": {"value": "IEC 60839-5-2:2016"},
  "hasPublisher": [{"orgName": {"value": "International Electrotechnical Commission"}}],
  "hasICS": [{"title": {"value": "Alarm and warning systems"}}],
  "hasClassification": [
    {"id": "https://w3id.org/i40/sto#RamiControlDevice",},
    {"id": "https://w3id.org/i40/sto#RamiFieldDevice",},
    {"id": "https://w3id.org/i40/sto#RamiCommunicationlayer",},
    {"id": "https://w3id.org/i40/sto#AsSecurity",
      "isDescribedin": [{"id": "https://w3id.org/i40/sto#AdministrationShell"}],
      "associatedWith": [
        {"id": "https://w3id.org/i40/sto#BdvaCyberSecurityTrust"},
        {"id": "https://w3id.org/i40/sto#DtpSecurityPrivacy"},
        {"id": "https://w3id.org/i40/sto#FiwareSecurity"}]]]}

```

“IEC 60839-5-2 by the IEC is about Alarm and warning systems and is classified in the areas RamiControlDevice, RamiFieldDevice, RamiCommunicationlayer; and AsSecurity (described in AdministrationShell, associated with BdvaCyberSecurityTrust, DtpSecurityPrivacy, FiwareSecurity)

## GraphQL Result 1 Notes

- You may notice that the result shape (nesting) exactly matches the query shape.
- (I've compressed the result to fit it on the page, but if you look in GraphQL, you'll see that's true).
- IEC 60832 is about alarm systems, so all its classifications (security) appear to be correct.

## GraphQL Query 2: Standards and Licenses

Let's find entities (eg standards) and their licenses:

```
query Licenses {  
  entity(where:{license:{}}) {id  
    license{id}}}
```

We get results, plus an error:

```
"errors": [{  
  "message": "Found 2 values for single-valued field 'license' from 'Entity'",  
  "path": ["entity", 3, "license"],  
  "locations": [{"line": 3, "column": 3}]}],
```

## GraphQL Query 2 Notes

Turns out that IEC\_62541 is dual-licensed under GPLv2 and OpenLicenseDocument. So our assumption that entities have a single license (removing `max:inf`) is not 100% true.

Here we're looking for entities and their licenses.

- I assumed entities have just one license so removed `max: inf` (more expensive to query), but it turns out the assumption is not 100% right (only 95% or so).
- GraphQL returns a very precise error, which allows us to find the exact query spot, and the exact data record that caused the error.

## GraphQL Query 3: ISO 15926

ISO 15926, in development for nearly 30 years, has been touted as the “lingua franca” for global interoperability.

Let's find the classifications and standards that it is related to:

```

query ISO_15926 {
  standard (where:{label:{value:{EQ:"ISO 15926"}}}) {
    comment {value}
    hasClassification {id}
    relatedTo {
      id
      label {value}
      comment {value}}}}

```

## GraphQL Query 3 Response

```

"standard": [{
  "comment": {"value": "Industrial automation systems and integration -- Integration of li
  "hasClassification": [
    {"id": "https://w3id.org/i40/sto#RamiProduct"},
    {"id": "https://w3id.org/i40/sto#RamiIntegrationLayer"},
    {"id": "https://w3id.org/i40/sto#AsConfiguration"},
    {"id": "https://w3id.org/i40/sto#AsEngineering"},
    {"id": "https://w3id.org/i40/sto#ProductLifeCycleManagement"}
  ],
  "relatedTo": [
    {"id": "https://w3id.org/i40/sto#DIN_SPEC_16592",
      "label": {"value": "DIN SPEC 16592"},
      "comment": {"value": "Combining OPC Unified Architecture and Automation Markup Langu
    {"id": "https://w3id.org/i40/sto#IEC_62541",
      "label": {"value": "IEC 62541"},
      "comment": {"value": "OPC Unified Architecture (OPC UA) is an industrial M2M communi
    ...

```

## ISO 15926 Complexity

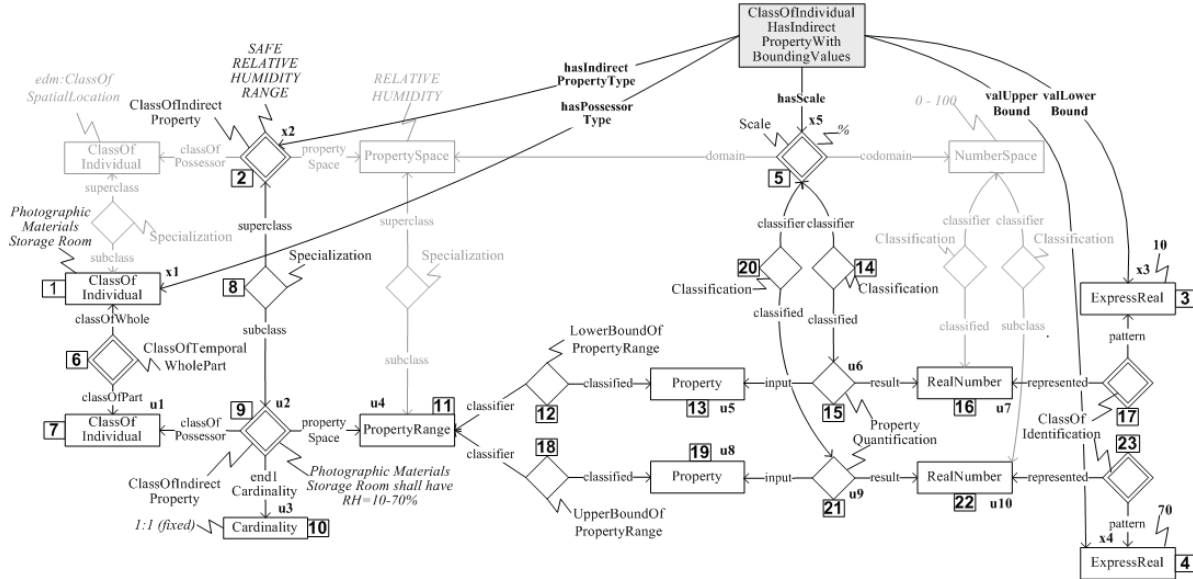
The complexity of ISO 15926 is difficult for most people to master.

Its approach to ontology modeling comes from the [BORO method](#) that uses:

- An Extensional (rather than linguistic) Criterion of Identity
- Four-dimensional modeling: every entity evolution or state is represented as another temporal part
- Non-well-founded Sets and Powersets

- Every relation is represented as a reified **Relationship** (diamond nodes in the diagram below)

Eg here's how to represent the allowed range of a parameter of some entity (tag or equipment):



## ISO 15926 Complexity Notes

This is template **CL-INDPTY-200 ClassOfIndividualHasIndirectPropertyWithBoundingValues** with definition “Any member of **EssentialType** class **hasPossessorType** has a **hasIndirectPropertyType** with a range of **valLowerBound** to **valUpperBound** **hasScale**”.

- It has 5 input parameters held by an N-ary relation named after the template name
- This is expanded to about 23 nodes and 100 triples
- Templates make it easier to **produce** the multitude of triples specified by ISO 15926
- But it's not clear whether templates simplify **querying** unless you use the N-ary relation...
- ... Which begs the question why you need the template expansion

## GraphQL Query 4: Concerns

I40KG includes about 160 “concerns” i.e. topics relevant to Industry (eg AI, DataAnalytics, etc).

```

query Concerns {
  concern{
    id
    label {value}}}

```

Results:

```

{
  "data": {
    "concern": [
      {"id": "https://w3id.org/i40/sto#IdentityManagement",
       "label": {"value": "Identity Management"}},
      {"id": "https://w3id.org/i40/sto#AsProcessPlanning",
       "label": {"value": "Process planning"}},
      {"id": "https://w3id.org/i40/sto#AI",
       "label": {"value": "Artificial Intelligence"}}, ...
    ]
  }
}

```

## GraphQL Query 5: Classification Concerns

Let's find which classifications are related to which concerns. We use prop frames defined as “A relation specifying that a viewpoint regards a Concern”:

```

query ClassificationConcerns {
  standardClassification(where:{frames:{}}) {
    id
    frames {id}}}

```

Results:

```

{"data": {
  "standardClassification": [
    {"id": "https://w3id.org/i40/sto#IIRAFunctionalViewpoint",
     "frames": [
       {"id": "https://w3id.org/i40/sto#IdentityManagement"},
       {"id": "https://w3id.org/i40/sto#AsProcessPlanning"}, ...
     ]
    }
  ]
}

```

## GraphQL Query 6: Standard Concerns

Similarly, property `hasTargetConcern` connects Standards to Concerns:

```
query StandardConcerns {
  standard(where:{hasTargetConcern:{}}) {
    id
    hasTargetConcern{id}}}
```

Result:

```
{"data": {
  "standard": [
    {"id": "https://w3id.org/i40/sto#DIN_77005_P1",
      "hasTargetConcern": [{"id": "https://w3id.org/i40/sto#DataLifecycleManagment"}]},
    {"id": "https://w3id.org/i40/sto#DIN_EN_50128",
      "hasTargetConcern": [{"id": "https://w3id.org/i40/sto#Safety"}]},
    {"id": "https://w3id.org/i40/sto#DIN_EN_50129",
      "hasTargetConcern": [{"id": "https://w3id.org/i40/sto#Safety"}]}, ...
```